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**COMMISSION ON GENETIC RESOURCES  
FOR FOOD AND AGRICULTURE**

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**REPORT ON  
THE STATE OF THE WORLD'S PLANT GENETIC RESOURCES**

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## Preface

### *Background and Preparation of the Report*

1. The Food and Agriculture Organization of the United Nations (FAO) Conference, at its Twenty-sixth session, agreed that a first Report on the State of the World's Plant Genetic Resources for Food and Agriculture should be developed, as part of the Global System for the Conservation and Sustainable Utilisation of Plant Genetic Resources for Food and Agriculture.<sup>1</sup> At its Twenty-seventh session, the Conference agreed that this should be done through a country-driven process under the guidance of the Commission, in preparation for the International Technical Conference on Plant Genetic Resources, which will be held in Leipzig, Germany, in June 1996. The preparation of a Report on the State of the World's Plant Genetic Resources, and its adoption at an International Technical Conference, were also recommended by the United Nations Conference on Environment and Development, in its Agenda 21,<sup>2</sup> and supported by the Conference of the Parties to the Convention on Biological Diversity.<sup>3</sup>

2. At its Sixth session in 1995, the Commission on Plant Genetic Resources considered and endorsed a draft outline for the Report on the State of the World's Plant Genetic Resources in line with the aims and strategy of the Fourth International Technical Conference for Plant Genetic Resources and its preparatory process.<sup>4</sup> The Report would describe the current situation of plant genetic resources for food and agriculture, at the global level, and identify the gaps and needs for their conservation and sustainable utilisation, as well as for emergency situations, thereby laying the foundation for the Global Plan of Action to be adopted by the International Technical Conference. It was agreed that the Report would emphasise the contribution of plant genetic resources for food and agriculture to world food security.

3. The Report on the State of the World's Plant Genetic Resources was developed through a participatory, country-driven process.<sup>5</sup> This process resulted in the preparation and submission of 151 Country Reports by Governments. These Country Reports were a primary source of information used in assembling this Report.

4. FAO provided Guidelines indicating the range of subjects and types of questions that might be addressed in Country Reports. The Guidelines indicated that in submitting Country Reports, Governments agreed that FAO could make the information in them publicly available. The scope and content of each Country Report was, however, determined by each Government. The Guidelines were not designed to solicit comprehensive quantitative data. Care has been taken in using and compiling data given in Country Reports.<sup>6</sup> Examples drawn from the Country Reports are provided for illustrative purposes only and are not meant to be exclusive or

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<sup>1</sup> A more complete description of the Global System is found in Article 7 of the FAO International Undertaking, and in Document CPGR-6/95/4 of the Commission on Plant Genetic Resources, "Progress Report on the Global System for the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture".

<sup>2</sup> Agenda 21, paragraph 14.60 (c)

<sup>3</sup> Decision 11/15 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indonesia, 6-17 November 1995.

<sup>4</sup> As endorsed by the FAO Conference at its Twenty-Seventh Session in 1993.

<sup>5</sup> A total of 157 countries participated in the preparatory process by submitting a Country Report, attending a sub-regional meeting, nominating a focal point, or some combination of these.

<sup>6</sup> For example, of the 151 Country Reports submitted, more than 70 countries provided information on the extent to which their *ex situ* collections were duplicated. In this case and most others, care must be exercised in making assumptions regarding the extent of duplication of collections in countries that did not offer information on this subject in their Reports. In other words, the fact that a certain number or percentage of countries mention that they have a particular problem in their genebank (e.g., equipment failures), cannot be interpreted as meaning that the others do not have such problems. The other countries may simply have not noted the existence of the problem in their Country Report.

comprehensive. Identification of a need or gap in a particular country is not, for example, intended to imply that other countries do not have a similar need.

5. Eleven sub-regional meetings were held at which 143 Governments and a number of international and non-governmental organisations were represented. During these meetings representatives presented their Country Reports and discussed common problems and opportunities. Information and input was given for the Report, and recommendations were made regarding the Global Plan of Action. Over 100 countries were visited by the Secretariat and its consultants to assist and facilitate countries' preparations for the International Technical Conference, and to gain first-hand knowledge.

6. In preparing the Report, FAO had access to the World Information and Early Warning System (WIEWS) database, data from FAO questionnaires concerning plant genetic resources, and the results of a number of scientific workshops held in support of the preparatory process for the International Technical Conference. As agreed by the Commission, the WIEWS is being updated using information from Country Reports and other information generated during the preparation of the Report. Concerning forest genetic resources, FAO had access to data from a separate questionnaire on forest genetic resources which was sent to all heads of forest services in Member countries. During preparations for the International Technical Conference, FAO established its first "electronic conferences" on the Internet, enabling scientists and others to provide technical inputs and discuss numerous matters of relevance to this Report. FAO also benefited significantly from the assistance of individual centres of the Consultative Group on International Agricultural Research (CGIAR), in particular, of the International Plant Genetic Resources Institute (IPGRI). Despite the large amount of information generated and assembled during the preparatory process for the International Technical Conference, gaps and deficiencies in information remain. Thus, the Report should be of assistance in revealing these gaps and helping us become aware of what is still not known or sufficiently understood. Additionally, this first Report should provide a benchmark against which future progress might be measured.

7. The Report is based on a more detailed technical working document, which is available in the language in which it was prepared, English.

8. The main body of this Report provides an assessment of the state of plant genetic resources for food and agriculture and current effectiveness of and capacity for their conservation, development and use. Background data, is provided in appendices, as well as in figures and tables following each chapter. Whilst every effort has been made to provide an accurate and complete assessment of the State of the World's Plant Genetic Resources in this first report, it necessarily reflects the limitations of the sources of information. It is expected that these limitations can be progressively overcome in future editions.

## Introduction

### *Plant Genetic Resources for Food and Agriculture*

9. Soil, water, and genetic resources constitute the foundation upon which agriculture and world food security are based. Of these, the least understood and most undervalued are plant genetic resources. They are also the resource most dependent upon our care and safeguarding. And they are perhaps the most threatened.

10. Plant Genetic Resources for Food and Agriculture (PGRFA) consist of the diversity of genetic material contained in traditional varieties and modern cultivars grown by farmers as well as crop wild relatives and other wild plant species that can be used for food, feed for domestic animals, fibre, clothing, shelter, wood, timber, energy, etc.<sup>7</sup> These plants, seeds, or cultures are maintained for the purposes of studying, managing, or using the genetic information they possess. As a term, "genetic resources" carries with it an implication that the material has or is seen as having economic or utilitarian value. Following the guidance of the Commission, emphasis in this Report is given to PGRFA which contribute to food security.

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<sup>7</sup> A more formal definition is found in Article 2 of the International undertaking: "(a) 'plant genetic resources' means the reproductive or vegetative propagating material of the following categories of plants: (i) cultivated varieties (cultivars) in current use and newly developed varieties; (ii) obsolete cultivars; (iii) primitive cultivars (land races); (iv) wild and weed species, near relatives of cultivated varieties; (v) special genetic stocks (including elite and current breeders' line and mutants;".

11. The conservation and sustainable utilization of plant genetic resources is key to improving agricultural productivity and sustainability thereby contributing to national development, food security, and poverty alleviation.<sup>8</sup> Today the world is not food secure in terms of access to food.<sup>9</sup> Eight hundred million people are undernourished and 200 million children under five years of age are underweight. In the next thirty years the world's population is expected to grow by over 2 500 million to reach 8 500 million. Improvements in yield on a reliable and sustainable basis will be needed to meet the demands of this growing population.

12. Before the founding of the modern nation state, indeed before the rise of the great early civilisations, our ancient ancestors were identifying, developing and using plant genetic resources. As they began to make the transition from hunting and gathering to agriculture some 10 000 years ago, they began to encourage the growth and production of certain favoured plant species - plants valued for religious, medicinal, food, flavouring or other utilitarian purposes. Slowly these practices led to the domestication of virtually all the agricultural species we depend on today.

13. Plant species undergoing domestication carried with them the myriad characteristics and defences which typically make wild plants so adapted to their environment and resilient to the challenges that might be posed by drought, pest and disease attack. As people migrated, plants migrated with them. Exposure to new environments placed new selection pressures on the various species. Encounters with new and changing human cultures meant that species came to be valued for different purposes. One group of people might encourage the development of the food potential of the species, another might refine it as a beverage. One might use a grain for making bread, others might select types more amenable to mixing with water for a porridge, or roasting. A tree species might be used for timber, fuel, food, or shelter.

14. For many hundreds of years, farmers and farm families in both developed and developing countries have been overseeing evolution in crops, combining genes in new and different ways to form "landraces" and varieties suited to their needs. Mutations might arise far away from where a crop's ancestors are indigenous and far away from the region of its domestication. The mutation might be noticed and made use of by a farmer, thus adding a valuable new trait to the crop's repertoire.

15. By the time Darwin wrote "Variation under Domestication," the first chapter of *The Origin of Species*, the world's major crops and other domesticated species were rich with diversity, a result of natural and human-influenced evolution over millennia. There was, for example, rice adapted to grow in metres of water and rice adapted to regions receiving only a tiny amount of rainfall annually. There were potatoes in a wide variety of shapes, sizes and colours - white, yellow, red, blue, and black, both inside and out. There were sorghums for bread, others for beer, and still others with strong fibrous parts used for basketry, brooms, and house construction. Within the domesticated species there was also diversity less immediately visible to the human eye - genetic resistance to pests and diseases, for example, and other characteristics conferred by genes.

16. When, in the early part of this century, the great Russian botanist and geneticist N. I. Vavilov travelled around the world, he noticed that diversity within agricultural crops was not equally dispersed. While potatoes could be found growing all over Europe and North America, the greatest diversity in forms was to be found in the Andes. Widely dispersed, the greatest diversity of rice was still to be found from Eastern India to Southern China; the greatest diversity of sorghum in savannah zones from Sudan to Chad. For the most part the greatest diversity of wild relatives and farmer varieties is still to be found in the areas Vavilov mapped out.

17. However, evolution is a continuous process. Mutations have generated new diversity, and people have continued to identify additional characteristics and combine genetic materials creatively to form new varieties. Maize, whose origin and primary area of diversity is in Central

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<sup>8</sup> Its contribution to sustainable agriculture and national development has been recognized as the ultimate objective of PGRFA conservation and use. Sub-regional meetings for East Africa and the Indian Ocean Islands, and for Southern Africa.

<sup>9</sup> McCalla AF (1994) Agriculture and Food Need to 2025: Why We Should Be Concerned. Sir John Crawford Memorial Lecture, CGIAR International Centres Week, October 27, 1994, Washington DC.

America, has a major secondary source of diversity in Africa, where many distinct types have been selected and developed over hundreds of years. In some cases the variation in such an area may exceed that in the ancestral homeland of the crop.<sup>10</sup> Crops such as rye and oats may have been carried along as weeds in barley and emmer fields from the Near East and Mediterranean and domesticated and developed in Europe in ancient times. This association with humans and the evolution of crops in widely varying environments is one reason why genetic diversity in domesticated species is not distributed in the same way as biological diversity in general.

18. In more recent times - that is, in the last 500 years - advances in transportation, chiefly maritime, made emigrants of even more plants. Species from the New World, such as beans, maize and rubber, were carried to Europe, Africa and Asia. New World tomatoes combined with pasta made from Near East wheat created the starting point for a "traditional" Italian dinner in today's Rome. Rice and soybeans from Asia travelled to the Americas where they became major crops.

19. Historically, plant genetic resources have contributed to stability in agro-ecosystems and provided the crucial raw material for the rise of modern, scientific plant breeding. They remain the foundation of evolution in crops - the natural resource which has allowed crops to be adapted to myriad environments and uses, and which will allow them to respond to the new challenges of the next century.

## Chapter 1 The State of Diversity

20. Many plant genetic resources which may be vital to future agricultural development and food security are threatened today. Country Reports indicate that recent losses of diversity have been large, and that the process of "erosion" continues. Of major concern is the irreversible loss of genes, the basic functional unit of inheritance and the primary source of the variation in the appearance, characteristics, and behaviour among plants. Gene complexes, and species can also be lost, and in effect become extinct. And plant varieties (e.g., a variety of wheat or cassava) can also disappear. While varieties can disappear without a corresponding loss in genetic diversity (the genes in a lost variety might still exist in other varieties), varieties as unique combinations of genes can have a particular value and immediate utility.

21. Few can doubt, however, that loss of diversity in PGRFA has been substantial. But, because no one knows how much diversity once existed in domesticated species, no one can say exactly how much has been lost historically. Nor is it possible to speak with complete confidence or precision about the rate of loss of diversity, because no comprehensive inventory has been made to inform us of what currently exists. Better inventories of resources still found *in situ* and detailed assessments of genetic diversity within *ex situ* collections will be needed to inform future work and measure future progress in the conservation of PGRFA.

22. The chief contemporary cause of the loss of genetic diversity has been the spread of modern, commercial agriculture.<sup>11</sup> The largely unintended consequence of the introduction of new varieties of crops has been the replacement -- and loss -- of traditional, highly variable farmer varieties.<sup>12</sup> This process was the cause of genetic erosion most frequently cited by countries in their Country Reports (Figure 1.1).

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<sup>10</sup> Harlan JR (1975) *Crops and Man*. Madison: American Society of Agronomy, Crop Science Society of America.

<sup>11</sup> Various indicators can be used to gauge roughly the spread of modern agriculture and modern cultivars, including increase in fertilizers, machinery, and irrigation. In addition, as traditional varieties have shared a history with particular peoples and cultures, the rapid decline in this century in numbers of human languages spoken also provides another indicator of the pressure on plant genetic diversity.

<sup>12</sup> Quantification of losses is difficult, because we have no way of really knowing what genetic diversity - as opposed to varietal diversity - they contained or how much of it still exists today. Furthermore, studies of cultivar replacement of potatoes in Peru, maize in Mexico and wheat in Turkey, indicate that some farmers may continue to use traditional varieties even after adopting modern varieties. They may do so to provide "insurance," or to use in fashioning new "varieties." (Brush, S. (1994) *Providing Farmers Rights through the in situ conservation of crop genetic resources*. Background study paper No. 2, Commission on Plant Genetic Resources.) FAO: Rome.

23. A number of countries provided specific examples of recent and often on-going replacement of farmer varieties and loss of wild relatives of cultivated crops:

- The Republic of Korea cites a study which showed that 74% of varieties of 14 crops being grown on particular farms in 1985 had been replaced by 1993.
- China reports that nearly 10 000 wheat varieties were in use in 1949. Only 1 000 were still in use by the 1970s. China also notes losses of wild groundnut, wild rice, and an ancestor of cultivated barley.
- Malaysia, Philippines and Thailand report that local rice, maize, and fruit varieties are being replaced.
- Ethiopia notes that native barley is suffering serious genetic erosion and that durum wheat is being lost.
- Large-scale erosion of local varieties of native crops and crop wild relatives is noted by Andean countries. Argentina points to losses of *Amaranthus* and quinoa.
- Uruguay states that many landraces of vegetables and wheat have been replaced. And Costa Rica reports replacement of native varieties of maize and *Phaseolus vulgaris*.
- Chile observes losses of local potato varieties, as well as oats, barley, lentils, watermelon, tomato and wheat.

24. One study providing an historical perspective on the loss of varieties was based on US Department of Agriculture information about varieties being grown by US farmers in the last century. It revealed that most varieties (after accounting for synonyms - one variety being known by different names) can no longer be found in either commercial agriculture or any US genebank. For example, of the 7 098 apple varieties documented as having been in use between 1804 and 1904, approximately 86% have been lost. Similarly, 95% of the cabbage, 91% of the field maize, 94% of the pea, and 81% of the tomato varieties apparently no longer exist.<sup>13</sup> The processes of modernization and varietal replacement, well documented in the US, have now occurred in many other countries and have surely led to substantial losses of unique genetic materials.

25. In Africa, the degradation and destruction of forests and bush lands is cited as a main cause of genetic erosion. Most countries in Latin America report major genetic erosion of forest species of economic importance. Cuba, Colombia, Ecuador, Panama, and Peru cite specific examples. Overgrazing and/or over-exploitation in general are also mentioned by a number of countries, including Cameroon, Burkina Faso, Guinea, Kenya, Morocco, Nigeria, Senegal, Saudi Arabia, and Yemen.

26. Civil strife and war have also contributed to genetic erosion in Africa and Asia. The threat to adapted varieties of staple crops in Rwanda is described in reports by CIAT and ICRISAT on their recent efforts to restore traditional planting materials.<sup>14</sup>

26. There is also an inextricable link between cultural and biological diversity.<sup>15</sup> The loss of genetic diversity - particularly of farmer varieties - is frequently associated with the loss of potentially useful knowledge about this material.

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<sup>13</sup> Fowler C (1994) *Unnatural Selection: Technology, Politics and Plant Evolution*, Yverdon: Gordon and Breach Science Publishers.

<sup>14</sup> CIAT (1994) Press Release, "Seeds of Hope" Program Takes Root in Rwanda, November 1994. Seeds of Hope: Report of the Inaugural Meeting at ILRAD, Nairobi, 21-2 September 1994.

<sup>15</sup> Guarino L (1995) Secondary sources on cultures and indigenous knowledge. In: Guarino L, Rao RV, and Reid R (eds.) *Collecting Plant Genetic Diversity: Technical Guidelines*, CAB International: UK.

27. No monitoring system exists to provide an early warning of impending genetic erosion. Marketing of improved varieties in areas rich in farmer varieties, for example, generally occurs without notification of authorities responsible for collection and conservation of PGRFA. The Sub-regional Meeting for East Africa and the Indian Ocean Islands, among others, cited the need to develop mechanisms that would identify threats to PGRFA and initiate action to prevent losses.

*Genetic Uniformity and Genetic Vulnerability*

28. The loss of genetic diversity in agriculture reduces the genetic material available for use by present and future generations. Developmental and evolutionary options for various species may, therefore, be shut off in the process. The concomitant increase in uniformity may also lead to greater risk and uncertainty. The US National Academy of Sciences described genetic vulnerability as "the condition that results when a widely planted crop is uniformly susceptible to a pest, pathogen or environmental hazard as a result of its genetic constitution, thereby creating a potential for widespread crop losses."<sup>16</sup> Even though a modern variety has been bred for resistance to a particular pathogen strain, a minor mutation in the pathogen can often break down that resistance overnight. The most famous example of the danger of genetic uniformity occurred with the 1840s pandemic of late blight (*Phytophthora infestans*) in potatoes, which provided the biological trigger for the "Great Famine" in Ireland. Currently, uniformity in the rootstock of California wine grapes and the resulting uniform susceptibility to a virulent disease is causing vineyards to dig up and replace their vines at the cost of hundreds of millions of dollars. And "Black Sigatoka" remains a problem with bananas.<sup>17</sup> In many cases it is necessary to return to the store of genetic diversity available for the crop species to find genes conferring resistance to the pest or disease. Often the only other alternative is to resort to chemical remedies, many of which also become ineffective as new resistant races of pests and diseases emerge. As the US National Academy of Sciences notes, "In a certain sense the use of pesticides on crops also reflects genetic vulnerability."<sup>18</sup>

29. Considerable genetic uniformity now exists in a number of crops. For example, F1 hybrids of rice - which expanded from five million hectares in 1979 to cover 15 million hectares in China in 1990 - share a common cytoplasmic male sterility source and the *sd-1* locus.<sup>19</sup> Sunflowers are similarly uniform. Protection against mildew attack on European barley is now increasingly dependent on one gene and one fungicide.<sup>20</sup> There is, however, no comprehensive or coordinated system for monitoring uniformity in agricultural species. And methodological tools which might help assess related genetic vulnerability have not been adequately developed.

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<sup>16</sup> National Academy of Sciences (1972) Genetic Vulnerability of Major Crops, Washington: NAS.

<sup>17</sup> INIBAP (1994) Annual Report.

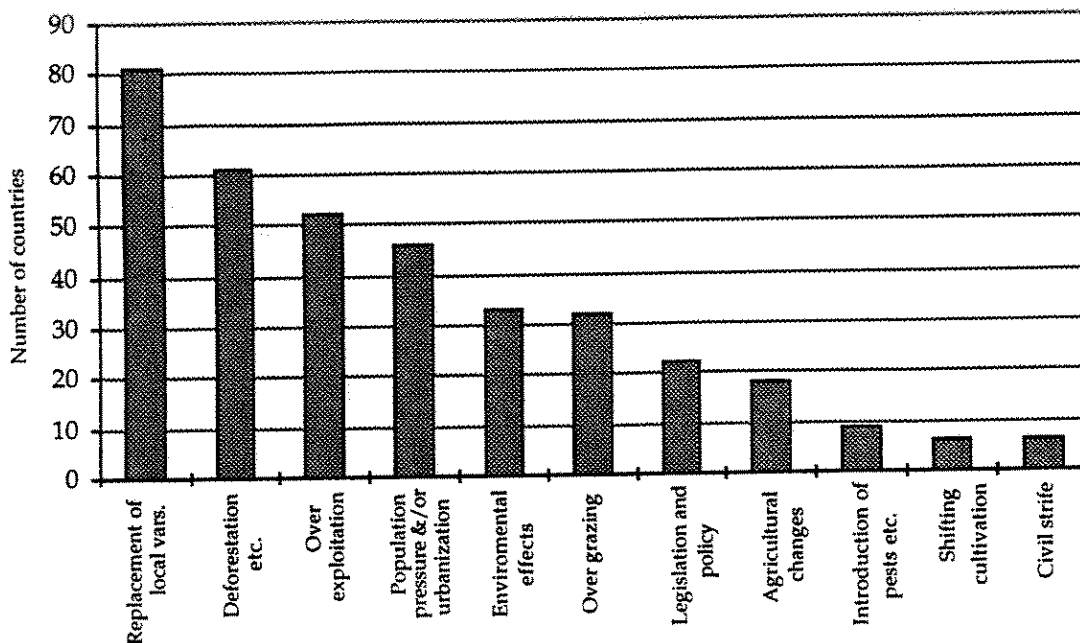
<sup>18</sup> National Academy of Sciences (1972) Genetic Vulnerability of Major Crops, Washington: NAS.

<sup>19</sup> National Research Council (1993) Managing Global Genetic Resources. Washington: National Academy Press.

<sup>20</sup> Wolfe M Barley diseases: maintaining the value of our varieties. Barley Genetics VI, Vol. II.



Figure 1.1 Main Causes of Genetic Erosion as Cited in Country Reports



## Chapter 2 The Status of Selected Species and Crops

30. Viewed from a global perspective, a remarkably small number of cereal crops provide a large proportion of total food requirements (Figure 2.1). However, when food energy supplies are analysed on a sub-regional level, a much greater number and type of crops emerge as significant. These include sorghum, millet, potatoes, sugar cane and sugar beet, soybean, sweet potatoes, beans, bananas and plantains (Figure 2.2). Cassava, for example, supplies over half of plant-derived energy for Central Africa, though it contributes only 1.6% globally. While many of these crops provide the main staples for millions of the world's poorer people, they receive much less attention or investment in terms of research and development. Other major food crops include groundnut, pigeon pea, lentils and cowpea. A substantial share of energy intake is also provided by meat, which is ultimately derived from forage and rangeland plants. These plants are, for the most part, poorly collected, documented and exploited. In addition, a large number of crops are important in supplying other dietary factors (proteins, fats, vitamins, minerals, etc.).

31. Most of the major staple crops are "mandate" crops of the various CGIAR centres and they are therefore in the most advantageous position to assess the overall global situation for them. Crops not covered by the CGIAR, however, are more difficult to assess, a situation which points to lack of information, absence of clear oversight and monitoring responsibilities, and the general lack of attention paid to these crops historically. Through the sub-regional meetings, Governments cited the need for more research, market development, inventories, and exchange of information. A number of meetings called attention to the importance of forest species, pasture and rangeland species, and species useful in dry and agriculturally-marginal environments.<sup>21</sup>

<sup>21</sup> Sub-regional meetings for East Asia, for Central and West Asia, for the Mediterranean, and for South America.

32. The following summary provides basic information about the status of some of the staple food crops. It should be noted that this is intended to be an illustrative rather than a definitive list of staple crops.

*Status of Major Staple Crops.*

33. Rice is the single most important crop globally, while wheat is the world's most widely cultivated crop. Together with maize, these crops alone provide more than half the global plant-derived energy intake (Figure 2.1). All three have been widely collected with wheat being the world's most collected crop. Gaps in collections remain, however. For example, landraces of rice from Madagascar, Mozambique, and Southern Asia are still under-represented in collections as are wild rice species from Eastern, Central and Southern Africa, and from Latin America.

34. Large collections of wheat are housed at the International Centre for Maize and Wheat Improvement (CIMMYT) and at the International Centre for Agricultural Research in the Dry Areas (ICARDA) in the CGIAR system, and in the national programmes of Russia, India, Germany and the USA. Table 2.1 provides information on major crop collections. Some 43% of rice accessions are stored in the six largest institutional collections (IRRI, China, India, USA, Japan, and Thailand), all of which observe international storage standards. The largest collection of rice germplasm is held at IRRI. Maize is stored in major collections in Mexico, India, USA, Russia, and at CIMMYT.

35. Extensive characterization and evaluation of accessions of these crops have been carried out, particularly in the international centres. For rice, the International Rice Research Institute (IRRI) has conducted a preliminary evaluation of much of its material for agronomic characteristics. For maize, an active conservation network is in place in Latin America, supplemented with a major initiative for evaluation, the Latin America Maize Project (LAMP). Core subsets have also been developed. While much evaluation data exists for wheat, rice, and maize, it is not all easily accessible. Global databases have not yet been developed and existing information is generally scattered throughout the scientific literature. IRRI has, however, developed an International Rice Genebank Collection Information System which accommodates passport, characterization and evaluation information.

36. Plant breeders have been successful in developing improved varieties of these three major crops, especially for favourable environments, and such varieties have had a major impact on food production increases world-wide. However, the impact in marginal areas has not been as great. While rice breeding has been successful in irrigated rice cultivation, breeding success has been more limited for non-irrigated rice cultivation. In wheat, while dramatic yield increases have occurred in Western Europe since 1960, much smaller yield increases have occurred in drier areas such as the South/East Mediterranean ecosystems. And in maize, many of the currently available improved varieties and hybrids are not suitable for non-intensive farming systems, as demonstrated by the continued cultivation of landraces by subsistence farmers.

37. Sorghum and millets are major staple food crops throughout much of Africa and Asia. Collections of these crops are held in a number of CGIAR institutes and national programmes. The largest collections of both crops are housed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which holds 22% of the global total of sorghum and 58% of the total accessions of pearl millet.<sup>22</sup> Regeneration methodologies are in need of further development. There are no global databases for either crop. Sorghum is extensively cultivated in America and China, where production is mainly for animal feed, though in Africa cultivation is mainly for human consumption. More than one third of the millets cultivated in India are improved varieties originating from ICRISAT.

38. The major starchy staple crops have historically received less attention than the major cereal crops. These include potato, sweet potato, cassava, and plantains. The largest collections of these crops are held by the CGIAR centres, but some countries also have large collections (Table 2.1). Gaps in collections are known to exist, particularly in the coverage of the wild relatives of these crops. Cultivated varieties are generally well represented in collections, although some

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<sup>22</sup> Most of ICRISAT's collections of these crops are stored under medium-term conditions and less than 50% have been duplicated for safety. CGIAR-SGRP Review Reports (1996) Report of External Review Panel of the CGIAR Genebanks Operations, ICRISAT.

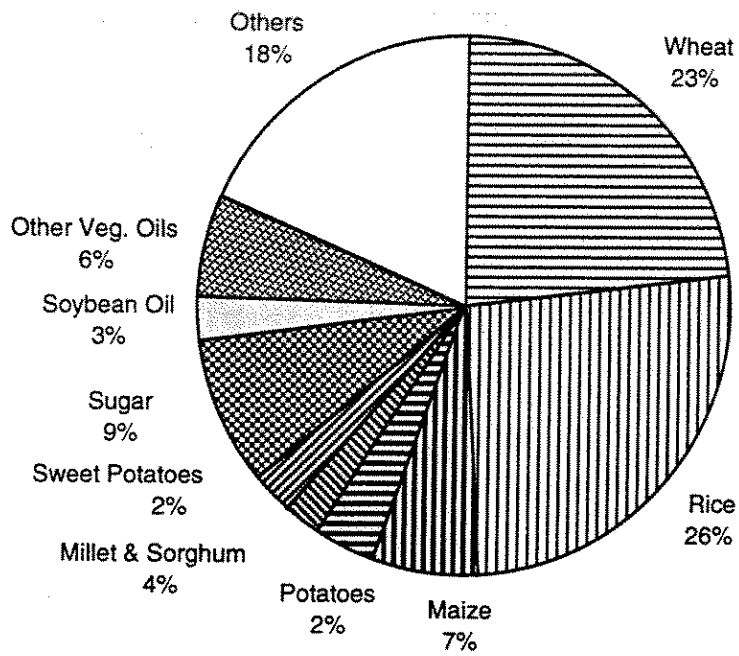
specific gaps remain. Conservation of these crops is generally in field genebanks, although *in vitro* conservation methods are becoming more common. The extent of safety duplication of collections is variable and the extent of characterization, evaluation and utilization of some collections has been limited by import restrictions and the need for virus indexing.

39. Several legume crops also play an important role in global food supplies. These include *Phaseolus* beans and soybeans. Major collections of soybean are found in China, at the Asian Vegetable Research and Development Centre (AVRDC), the USA, Brazil, and Ukraine, while the largest collection of *Phaseolus* is held at the International Centre for Tropical Agriculture (CIAT), with important national collections in Mexico and Brazil. Gaps in collections are particularly evident for *Phaseolus*, where many wild relatives are under-represented. Characterization and evaluation of collections is generally incomplete. Core collections of *Phaseolus* have been defined by CIAT and the USA.

#### *Minor Crops and Under-utilised Species*

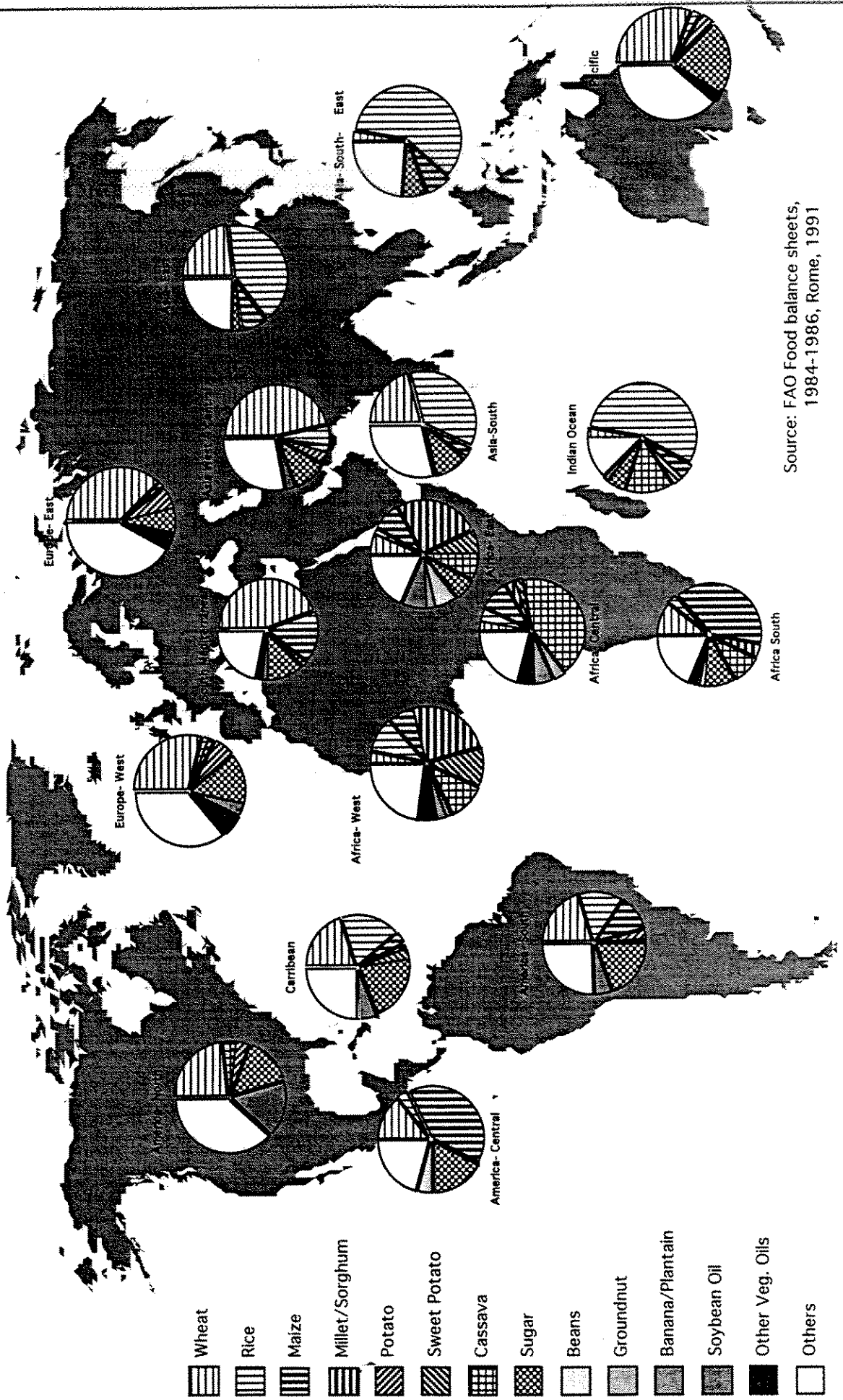
40. Most of the sub-regional meetings held during the preparatory process for the International Technical Conference called attention to the fact that a much larger group of plants than the major staples are important from a local, national or regional perspective. These include crops such as teff, bambara nut, fonio, minor millets and oca which are important food to large numbers of people.

41. Many sub-regional meetings concluded that more attention to minor and under-utilised crops was needed. The sub-regional meeting for West and Central Africa, for example, called for cooperation with local populations to promote sustainable management of such crops. The sub-regional meetings for East Africa and for Southern Africa suggested that the mandate of international agricultural research centres be broadened to include a wider range of crops. Several national and CGIAR programmes have recently accepted some responsibilities for certain minor or under-utilised crops including, rice bean, moth bean, amaranth, winged beans, faba beans and adzuki bean.

**Figure 2.1 Global Share of Dietary Energy Supply from Different Plant Sources**

Source: FAO Food balance sheets, 1984-1986, Rome, 1991

**Figure 2.2 MAIN STAPLE FOOD SUPPLY IN THE SUBREGIONS OF THE WORLD**



Source: FAO Food balance sheets, 1984-1986, Rome, 1991

Table 2.1 Selected crops: largest six ex situ germplasm collections

Crop	Total World Accessions	Major holders										
		1	2	3	4	5	6	7	8	9	10	
wheat	774 500	CIMMYT	USA	Russia	India	Germany	India	6	6	6	Italy	5
barley	485 000	Canada	USA	ICARDA	United K'dom	USA	United K'dom	6	6	6	Russia	5
rice	408 500	IRRI	China	India	USA	USA	USA	8	8	5	Thailand	4
maize	277 000	Mexico	India	USA	Mexico	Brazil	Russia	7	4	4	Colombia	4
Phaseolus	268 500	CIAT	USA	USA	AVRDC	Brazil	Brazil	10	3	3	Russia	3
soybean	174 400	China	USA	USA	USA	Brazil	Brazil	5	4	4	Russia	3
sorghum	168 500	ICRISAT	USA	USA	USA	USA	USA	6	4	4	Australia	4
Brassica	109 000	India	United K'dom	Germany	Germany	USA	USA	8	6	6	Korea, Rep.of	3
cowpea	85 500	IITA	Philippines	USA	USA	AVRDC	AVRDC	7	6	6	Indonesia	5
groundnut	81 000	USA	India	ICRISAT	India	ICRISAT	China	8	6	6	Zambia	2
tomato	78 000	USA	AVRDC	Philippines	Philippines	Russia	Russia	4	4	4	Colombia	3
chickpea	67 000	ICRISAT	ICARDA	Pakistan	Pakistan	USA	USA	9	8	8	Russia	4
cotton	49 000	India	France	Russia	Russia	USA	USA	6	5	5	China	3
sweet potato	32 000	CIP	Japan	USA	USA	Peru	Peru	6	6	5	(several)	4
potato	31 000	CIP	Colombia	Germany	USA	USA	USA	8	4	4	Czech Repub.	4
faba bean	29 500	ICARDA	Germany	Italy	Italy	Spain	Spain	6	6	6	France	6
cassava	28 000	CIAT	Brazil	IITA	IITA	Uganda	Uganda	6	5	5	Malawi	4
rubber	27 500	Malaysia	Brazil	Cote d'Ivoire	Cote d'Ivoire	Liberia	Liberia	4	4	4	Indonesia	2
garlic/onion	25 500	Germany	United K'dom	India	India	Russia	Russia	5	6	6	France	4
lentil	25 000	ICARDA	USA	Russia	Russia	Iran	Iran	7	4	4	India	3
sugarbeet	24 000	Germany	France	Netherlands	Netherlands	Yugoslavia	Yugoslavia	9	7	7	Japan	5
oil palm	21 000	Zaire	Malaysia	Brazil	Brazil	Ecuador	Ecuador	3	1	1	Indonesia	1
coffee	21 000	Cote d'Ivoire	France	Cameroon	Cameroon	Costa Rica	Costa Rica	7	6	6	Colombia	5
sugarcane	19 000	Brazil	India	USA	USA	Domin.Rep.	Domin.Rep.	11	8	8	Venezuela	5
yam	11 500	IITA	Cote d'Ivoire	India	India	Philippines	Philippines	5	4	4	Solomon Is.	4
banana/plantain	10 500	INIBAP	France	Honduras	Honduras	Philippines	Philippines	6	5	5	Cameroon	5
cocoa beans	9 500	Brazil	Trinidad/Tob.	Venezuela	Venezuela	France	France	7	6	6	Colombia	5
taro	6 000	Malaysia	Papua NG	India	India	USA	USA	8	7	7	Philippines	6
coconut	1 000	Sierra Leone	Venezuela	France	France	India	India	13	11	11	Philippines	9

Source: WIEWS database & CGIAR-SGRP Genebank Review

### Chapter 3 *In Situ* and On-Farm Management of Plant Genetic Resources

42. During the preparatory process for the International Technical Conference, the lack of integrated conservation strategies for PGRFA, based on the complementarity of *in situ* and *ex situ* approaches, was noted.<sup>23</sup> And there were proposals for increased resources to be allocated for *in situ* conservation, especially in developing countries.<sup>24</sup> The need to develop several different *in situ* approaches to PGRFA was identified during the preparatory process:

- specific conservation measures for crop wild relatives, and wild food plants, particularly in protected areas;<sup>25</sup>
- sustainable management of rangelands, forests and other managed resource areas;<sup>26</sup>
- conservation of landraces or traditional crop varieties on-farm, and in home gardens.<sup>27</sup>

43. Traditionally, *in situ* conservation programmes have been important primarily for the conservation of forests and sites valued for their wildlife or ecological value (e.g., wetlands).<sup>28</sup> While *in situ* conservation is common for forest genetic resources, there is potential to use *in situ* approaches for the conservation of other PGRFA.<sup>29</sup>

44. Worldwide, protected areas number 9 800 and cover approximately 926 349 000 hectares of the earth's surface.<sup>30</sup> However, with the exception of some forest tree species, conservation of indigenous wild species of agricultural importance generally occurs as an unplanned result of nature protection.<sup>31</sup> There are, however, a number of exceptions which could serve as examples of conservation activities that protected areas could undertake in relation to PGRFA. Several countries use protected areas for the conservation of wild fruit trees, including Germany, the Commonwealth of Independent States, Sri Lanka, and Brazil. Israel has conducted pioneering research on "dynamic gene preservation" for the *in situ* conservation of wild emmer wheat, while Turkey has recently initiated an *in situ* project, with support from the Global Environment Facility, to conserve crop-related wild relatives of wheat, barley, and other species of agricultural interest. Given the importance of wild food plants for the local livelihoods of many

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<sup>23</sup> As defined in the Convention on Biological Diversity, "*in situ* conservation means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties".

<sup>24</sup> Regional meeting for Europe, and sub-regional meeting for East Africa and the Indian Ocean Islands.

<sup>25</sup> Sub-regional meetings for South America, and for West and Central Africa.

<sup>26</sup> Sub-regional meetings for Southern Africa, and for West and Central Africa.

<sup>27</sup> Sub-regional meetings for Eastern Africa and the Indian Ocean Islands, for Southern Africa, and for West and Central Africa.

<sup>28</sup> Synthesis Reports for East Africa, for Europe, and for West Africa.

<sup>29</sup> Synthesis Report for Europe.

<sup>30</sup> IUCN (1993) United Nations List of National Parks and Protected Areas. Prepared (1994) by WCMC and CNPPA. IUCN, Gland, Switzerland and Cambridge, UK.

<sup>31</sup> Synthesis Report for Europe.

poor communities additional efforts could be made to address their conservation needs in protected areas.<sup>32</sup>

#### *Ecosystem Management for the Conservation of PGRFA*

45. Most plant genetic resources of importance for food and agriculture are located outside existing protected areas, in ecosystems such as farms, rangelands, forests, and other managed resource areas. Many of these are common property resource areas.<sup>33</sup> Frequently, PGRFA in these ecosystems are not just being conserved, but are also being managed and developed. Due attention will thus need to be paid to both conservation and productivity questions, and to associated economic and social constraints. Rangelands, for example, are very often subject to overgrazing and other degradation factors.<sup>34</sup> Forests are also subject to degradation and destruction, due to mismanagement and deforestation for agriculture and other land uses. Several countries in West Africa, nevertheless, reported on the important role of local communities using traditional methods in the sustainable management of ecosystems<sup>35</sup>.

#### *On-Farm Management of PGRFA*

46. In many countries, farmers practice *de facto* conservation of genetic diversity by maintaining traditional landraces. Farmers also engage in management practices, including the conscious selection of seeds for various characteristics, certain other forms of breeding, and the saving seed for replanting. Such practices go beyond pure conservation by improving and developing PGRFA. Farmers engaged in these types of efforts typically have limited financial resources and farm on marginal lands. Access to appropriate, scientifically-bred improved varieties may be limited, explaining the fact that they are substantially self-provisioning in terms of seed for planting. Over one billion people live in farm families, where the responsibility for management and improvement of PGRFA currently resides with the family itself.

47. In the absence of realistic expectations that appropriate improved seed varieties will reach these people in the near future, specific projects have been initiated to support and develop "on-farm" management, conservation and improvement of PGRFA. These projects draw upon recent academic works calling attention to the sophistication of the indigenous knowledge and the effectiveness of many traditional practices in conserving and developing PGRFA. Many projects involve non-governmental organisations working in co-operation with universities, research institutes and government genebanks, as some examples from Country Reports illustrate:

- In Ethiopia, landraces of the most important food crops including teff, barley, chick pea, sorghum and faba bean, are maintained *on farm* through a programme of the country's Biodiversity Institute in cooperation with the African Seeds of Survival Programme;
- In Sierra Leone, a project for the *on farm* conservation of rice and other crops has been initiated at Rokpur Rice Research Institute, in the context of the Community Biodiversity Development and Conservation Programme;
- In the Philippines, the Non-Governmental Organizations (NGOs) SEARICE & CONSERVE work with 140 farmer "curators" in Mindanao for the conservation and testing of rice and maize varieties, while a joint NGO-University initiative, the MASIPAG programme, promotes on farm conservation of rice and other crops;
- In Bolivia, there are four major projects which concern *in situ* conservation of crops in protected areas involving native Bolivian communities;
- In Mexico, the *Universidad Autónoma Chapingo*, and *Universidad Autónoma de Mexico* are engaged in *in situ* conservation efforts using traditional cropping methods in major projects in Guanajato, Chiapas, Yucatán, and Veracruz states.

<sup>32</sup> Regional meeting for Europe; sub-regional meeting for South America. The sub-regional meeting for South, South East Asia and the Pacific also stressed the importance of ensuring the active participation of local communities in the management of protected areas, in order to help reconcile the sometimes conflicting goals of conservation and local livelihood security.

<sup>33</sup> Scoones, I; Melynk, M and Pretty JN (1992) *The Hidden Harvest: Wild Foods and Agricultural Systems*, an annotated bibliography, IIED, London with WWF, Gland and SIDA, Stockholm.

<sup>34</sup> Sub-regional meeting for the Mediterranean.

<sup>35</sup> Synthesis Report for West Africa.



48. Additionally, in Europe, the EU has recently established legislation which financially supports on farm conservation measures.<sup>36</sup>

49. Few projects are limited to pure *in situ* conservation. Most are linked to support for traditional agricultural systems, to crop improvement through participatory approaches to plant breeding, or to community-level gene banks (i.e., a form of *ex situ* conservation). In many marginal areas, where the majority of small scale farmers live, the strengthening of on-farm management and improvement of PGRFA may be an appropriate strategy for improving farmers' livelihoods as well as maintaining rural populations and preventing land degradation.<sup>37</sup> Such efforts would utilise existing human resources - farmers and farm families - to develop and improve planting materials on the farm and in home gardens.

50. Mechanisms for cooperation and mutual exchange of expertise, information, germplasm and other resources between the formal sector programmes and *in situ*, including on-farm programmes, are poorly developed. Good coordination mechanisms, such as through national committees, are therefore very important to facilitate the involvement of farming and indigenous communities in the management of plant genetic resources, and to maximise the benefits of complementarity between *in situ* and *ex situ* efforts. During the preparatory process it was also recognised that on-farm conservation activities should be integrated with national strategies for the conservation and utilisation of PGRFA. It was suggested that policies and regulations which promote sustainable on farm conservation of crops and liberalise marketing of genetically diverse planting materials should be established.<sup>38</sup>

51. The preparatory process for the International Technical Conference identified a number of activities which could be promoted to strengthen on-farm management of PGRFA, and contribute to the improvement of farmers' livelihoods, and in particular resource poor farmers. These needs included:

- promotion, support, and improvement of farmer-selection of varieties to improve yield, yield stability, stress tolerance, nutritional and other desirable characteristics.<sup>39</sup> Such support could include participatory plant breeding approaches;<sup>40</sup>
- improved linkages between *ex situ* conservation and *in situ* conservation, including greater utilisation of landraces from *ex situ* collections, where they meet farmers needs.<sup>41</sup> This approach may also be applicable in PGRFA rehabilitation programmes serving areas suffering PGRFA losses due to civil strife or natural disasters;<sup>42</sup>
- promotion of on-farm, farmer-level seed production, and support for informal seed exchange mechanisms.<sup>43</sup>

<sup>36</sup> EEC Council Regulation No 2078/92

<sup>37</sup> Sub-regional meeting for the Mediterranean.

<sup>38</sup> Sub-regional meetings for Central and West Asia, for the Mediterranean, and for Southern Africa; regional meeting for Europe, Synthesis Report for Southern Africa.

<sup>39</sup> Berg T; Bjornstad A; Fowler C and Skroppa T (1991) Technology Options and the Gene Struggle. Aas: NORAGRIC/Agricultural University of Norway.

<sup>40</sup> Sub-regional meetings for the Mediterranean; for South America; for Central and West Asia; for West and Central Africa; for South and South East Asia and the Pacific; and for Central America, Mexico and the Caribbean.

<sup>41</sup> Guarino, L and Friis-Hansen, E (1995) collecting plant genetic resources and documenting associated indigenous knowledge in the field: a participatory approach. In: Guarino, L; Ramanatha Rao, V and Reid, R (eds) Collecting Plant Genetic Diversity: Technical Guidelines. CAB International: Oxon, UK.

<sup>42</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; for Southern Africa, and for West and Central Africa.

<sup>43</sup> Cromwell E and Wiggins S (1993) Sowing Beyond the State: NGOs and Seed Supply in Developing Countries. Overseas Development Institute: London.

52. There are numerous examples of local varieties being lost due to war, civil strife and natural disasters. In such circumstances, large numbers of farm families can be forced to migrate, leaving crops behind in the fields and losing seed for planting the next season. In such situations, restoration of locally-adapted seed can play an important role in rebuilding agricultural systems.

53. In Rwanda, CIAT estimated that improved varieties of various crops imported from outside of the region would substantially reduce yields compared to traditional Rwandan farmer varieties, because the imported varieties would not be well adapted to local conditions. Several CGIAR centres cooperated in identifying Rwandan landraces stored in genebanks outside the country. Seed of beans, sorghum, millet and maize is being multiplied and returned to farmers for planting. This relatively inexpensive programme is increasing food supplies, reducing foreign assistance costs, and helping to build a sustainable agricultural system.

54. Initiatives such as those in Rwanda are often taken on an *ad hoc*, voluntary basis. Institutional responsibilities have not been agreed by international or regional bodies. No coordinating mechanism exists. Mobilisation and fund-raising for every emergency begin anew each time. In many cases, there is no response at all dealing with the PGRFA aspect of the tragedy. Recent FAO initiatives on seed security link the conservation of local cultivars with germplasm utilisation, through on-farm seed production, for distribution to local farmers and neighbouring communities. This approach will also ensure rapid response to emergency seed needs at relatively low cost, while ensuring the conservation of local crop genetic diversity.

#### Chapter 4 *Ex Situ Conservation*

55. The threat of genetic erosion, first voiced by two scientists, Harlan and Martini, in a technical article in the 1930s, led to the first FAO international initiatives in the following decade and eventually to the establishment in 1974 of the International Board for Plant Genetic Resources (IBPGR), then an independent Board with its secretariat supplied by FAO, to co-ordinate an international plant genetic resources programme.

56. The practical result of these and other events was a concerted effort to collect and conserve plant genetic resources (generally *ex situ*, in genebanks) before they disappeared. It is important to note that this effort in the 1970s took place in an atmosphere of crisis. Experts believed - with good reason - that they had very little time in which to collect and safeguard these resources from extinction in the field.

57. The urgency of the moment and haste of action resulted in two achievements:

(a) the piecing together of a melange of institutional structures, funding sources, strategies, experts, and quickly-constructed genebanks to tackle the crisis; and,

(b) the rescue and amassing of a huge collection of plant genetic resources.

58. Today's genebank "system" and the collections in it were largely formed during the crisis-years of the 1970s and early 1980s. As we enter the 21st century, we do so with all the strengths - and drawbacks - of this history.

59. The number of genebanks has grown rapidly since the early 1970s, when there were fewer than ten, holding perhaps no more than a half million accessions. A total of 1 308 genebanks are now recorded in the WIEWS database. Based on this database, and information provided in Country Reports, approximately 6.1 million accessions are stored worldwide in *ex situ* germplasm collections, including approximately 527 000 accessions stored in field genebanks. Information on accessions held *in vitro* is incomplete. Perhaps fewer than 37 600 accessions are being conserved in this manner.<sup>44</sup> The total includes many working collections

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<sup>44</sup> According to FAO WIEWS database.

maintained by plant breeders, as well as those collections established specifically for long-term conservation.<sup>45</sup> Table 4.1 provides information on the percentage of genebanks and accessions of the global total located in each region, while Tables 4.2, 4.3 and 4.4 give information on the major national, regional and CGIAR genebanks and their collections.

60. Collections vary in the crop species covered, the extent of the crop gene pool covered, the type of accession (wild relatives, landraces, or advanced cultivars) and the origin of material. A breakdown of world *ex situ* collections by major crop groups is given in Figure 4.1.

61. The most current information from the WIEWS database indicates that over 40% of all accessions in genebanks are cereals. Food legumes are the next largest category constituting about 15% of global collections stored *ex situ*. Vegetables, roots and tubers, fruits, and forages, each account for less than 10% of global collections.<sup>46</sup> Medicinal, spice, aromatic, and ornamental species are rarely found in long-term public collections. Aquatic plants of relevance for food and agriculture are likewise not found in such collections.<sup>47</sup>

62. Information in the WIEWS database indicates that 48% of accessions for which the type is known are advanced cultivars or breeding lines, while 36% are landraces or old cultivars and about 15% are wild or weedy plants or crop relatives. However, these estimates are subject to wide error as the type of accession is only known for one third of all accessions. The collections of the CGIAR genebanks are more heavily weighted towards landraces. As a whole, these collections consist of 59% landraces and old cultivars, 14% wild and weedy relatives and 27% advanced cultivars and breeders' lines.

63. Large differences also exist in the percentage of materials in *ex situ* collections which is indigenous. The national collections of Greece, Turkey and many southern Africa countries consist largely of indigenous materials. In contrast, the *ex situ* collections of the US contain 19% indigenous materials and the *ex situ* collections of Brazil, 24%.<sup>48</sup>

64. Because there has never been a comprehensive inventory of plant genetic resources for food and agriculture (wild and domesticated, *in situ* and *ex situ*), it is impossible to say how representative current *ex situ* collections are of total diversity existing *in situ*. Collections of cereals landraces are probably more "complete" than those of pulses, most root crops, fruits, and vegetables (with the possible exceptions of potato and tomato).<sup>49</sup> Coverage of wild relatives is generally acknowledged to be very low. Coverage of many forage species is scant. And only a relatively small number of the main forest tree plantation species are conserved *ex situ*, mainly through living collections, including in internationally coordinated programmes. ILRI communicated there was a generalised need for collecting of forages and fodder trees.

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<sup>45</sup> This number is obtained by using the larger of the numbers of accessions per country as reported in the Country Reports, and as recorded in the WIEWS database. Discrepancies in the number between the two sources is frequently caused by the inclusion or exclusion of working collections.

<sup>46</sup> Percentages are based on WIEWS data - not updated by information from Country Reports. Information from Country Reports documents a larger number of accessions in genebanks than recorded in WIEWS. However, the Country Reports do not provide a breakdown of accessions by category, therefore, these percentages are based on the smaller number of accessions documented in WIEWS.

<sup>47</sup> ICLARM stated that certain algae should be collected.

<sup>48</sup> Countries volunteering information on this subject in their Country Reports may have different ways of defining "indigenous." The purpose for which the genebank was developed also influences the types of materials conserved. Some programmes have perceived their mission as conserving materials of national origin, while others have assembled collections according to the needs of breeding programmes. In the latter case, a smaller percentage of "indigenous" materials would be expected to be conserved in the genebank. Finally, access to exotic materials and the capacity to conserve additional accessions have limited the composition of collections of a number of countries.

<sup>49</sup> Plucknett, Donald, et. al (1987) Genebanks and the World's Food. Princeton: Princeton University Press.

65. A large number of countries in their Country Reports pointed to lack of knowledge about indigenous plant genetic resources and the need for surveys, inventories, taxonomic studies, and other analyses of existing diversity.<sup>50</sup> Given the emphasis on filling certain identified gaps in existing collections and adding new species to collections (e.g., "under-utilised crops," ornamentals, spices, aromatic, medicinal, forage species, etc.), the absence of good inventories becomes a bigger and bigger obstacle to planning and prioritising of collecting and other conservation activities.

#### *Status of the Collections in Long-Term Storage*

66. Most countries do not have facilities for the long-term *ex situ* storage and conservation of plant genetic resources. Although 77 countries report that they have seed storage facilities suitable for medium/long-term storage, probably fewer than half can offer secure, long-term management of accessions.<sup>51</sup> (Notably, one of the world's largest genebanks, that of the Vavilov Institute in Russia, does not currently have long-term storage facilities.) Additionally, twelve international CGIAR and regional genebanks have secure long-term facilities.

67. A number of countries have offered in principle to make their *ex situ* conservation facilities available or to host regional facilities for safe-keeping of material from other countries under mutually agreed arrangements. These countries include: Ethiopia, Islamic Republic of Iran, Kenya, Pakistan, Spain, Turkey, Turkmenistan, Uzbekistan, India, Argentina, Brazil, Ecuador, Chile, China, the US, and the Nordic Genebank.

68. No comprehensive, independent review of genebank facilities and operations has been made to date. Nevertheless, it is evident that each region has genebanks which operate at very high standards. However, for each such facility there are many others that are perhaps incapable at present of performing the basic conservation role of a genebank.

69. A number of countries included information in their Country Report on the condition of genebank facilities, and identified various constraints. In particular, these countries cited:

- Equipment problems, particularly in cooling units,<sup>52</sup> lack of seed cleaning and humidity control equipment.
- Insecurity of electricity supply and the need for back-up generators.<sup>53</sup>
- Difficulties in seed drying, especially in the humid regions of Africa, Asia, and Latin America.<sup>54</sup>

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<sup>50</sup> Among those countries were: Cameroon, Central African Republic, Congo, Gabon, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Mauritius, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania, Togo, Zimbabwe, Benin, Niger, Nigeria, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Panama, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent, Trinidad and Tobago, Canada, United States, Argentina, Bolivia, Brazil, Colombia, Venezuela, Cambodia, China, Japan, Cook Islands, Papua New Guinea, Samoa, Bangladesh, India, Maldives, Malaysia, Myanmar, Philippines, Thailand, Austria, Estonia, Lithuania, Poland, Ukraine, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Iran, Iraq, Uzbekistan, Egypt, Cyprus, Jordan, and Turkey.

<sup>51</sup> Almost 400 genebanks are listed in the WIEWS database as offering long or medium term facilities. The security offered depends on the standards of the facility and its equipment, the reliability of power supplies, the provision of reasonable safety duplication and regeneration procedures, and the quality and effectiveness of management.

<sup>52</sup> Including: Cameroon, Congo, Guinea, Madagascar, Senegal, Togo, Uganda, Egypt, Iraq, Vietnam, and Romania. Guinea, for example, reported that its cold chambers are not working and Romania reported that its long-term storage unit is not operational.

<sup>53</sup> This has been reported by, amongst others, Cameroon, Angola, Malawi, Cuba, Bangladesh, Egypt, Iraq, and Turkey.

<sup>54</sup> Virtually no working seed dryers were encountered during visits by FAO to genebanks in a number of Eastern and Southern African countries. Cyprus, Moldova, Nepal, and Vietnam also note lack of seed drying capacity.

70. A large number of genebanks were built in the 1970s and 1980s seemingly without provisions being made for on-going financial support by either donor or host governments. Some of these genebanks have now closed.<sup>55</sup> A number are in a state of rapid deterioration, noticeable not only in the physical structures and equipment problems, but also more ominously in the high regeneration requirements. Nordic support for the SADC regional facility is virtually the only known example of a long-term commitment by a donor - in this case, 20 years - to the operation of a facility they have constructed.

71. About half of those submitting Country Reports made note of the degree to which their collections were duplicated for safety. Of those, eleven countries (15%) reported that their collections (436 000 accessions) were fully duplicated. Of the remainder, 51 countries (71%) reported partial duplication and ten (14%) reported no safety duplication at all. It is possible, indeed certain, that some accessions are duplicated and found in multiple genebanks unbeknownst to a particular national genebank. Lack of data on individual accessions currently prevents a comprehensive assessment of the degree of duplication or redundancy between collections. Some individual collections are known to have sizeable numbers of distinct accessions outside long-term conditions combined with very low rates of safety duplication.<sup>56</sup>

72. Information does not exist to determine how many accessions in *ex situ* collections are "unique" and how many are duplicates on a global basis. However, a study published in 1987, estimated that 35% of the accessions of 37 crops were distinct.<sup>57</sup> The remainder were duplicates. This study was based on 2.5 million total accessions regardless of storage conditions. With the global total exceeding twice that figure today, and being unable to account for the steep rise by the past decade's collecting missions alone, one might assume that the degree of unintended and redundant duplication is now higher. Indeed, operating on this premise, the recent study of global plant genetic resources undertaken by the US National Research Council called for redundancies to be minimized.<sup>58</sup>

#### Regeneration

73. Even under optimal *ex situ* storage conditions, seed viability will decline, necessitating regeneration in order to replenish stocks.<sup>59</sup> Assuming the regeneration cycle to be 10 years or more on average, one would expect routine annual regeneration needs to amount to less than 10% of accessions. However, some 95% of countries responding with specific information on regeneration report a far higher level of need. Such a situation is an indicator of poor storage conditions, lack of funds or facilities for regeneration, poor management, or a combination of such factors, in many of the world's genebanks. Furthermore, most countries report that they are having some form of difficulty regenerating their materials, pointing to a need for support and capacity building. Figure 4.2 shows the percentage of national collections in need of regeneration by country. Figure 4.3 indicates the major constraints to regeneration as volunteered by countries in their Country Reports.

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<sup>55</sup> See, for instance, the Tunisia Country Report.

<sup>56</sup> A recent external review of CGIAR genebank operations cited several examples. It found that 80% of over 100,000 accessions at the International Crops Research Institute for the Semi-Arid Tropics was not in long-term storage and that ICRISAT should "urgently review its arrangements for safety duplication..." Report of the External Review Panel of the CGIAR Genebank Operations, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

<sup>57</sup> Plucknett D, et. al. (1987) *Genebanks and the World's Food*. Princeton: Princeton University Press.

<sup>58</sup> National Research Council (1993), *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*. Washington: National Academy Press.

<sup>59</sup> In contrast to regeneration, "multiplication" should take place when stocks are reduced due to distribution and use. In practice, materials under long-term storage should rarely need to be multiplied. Users such as breeders, should be supplied from short-term or working collections. Conversely, regeneration of working collections indicates that they are not being used and should probably be moved to long-term storage.

74. FAO estimates that as many as one million accessions may now be in need of regeneration.<sup>60</sup> Given the large number of collections made in the past two decades and the sub-standard conditions now existing in many genebanks, the need/demand for regeneration will remain strong for many years. Better coordination, increased cooperation among genebanks, and improvements in information and documentation systems could reduce current and future regeneration needs.

#### *Characterization and Documentation*

75. Much of the world's PGRFA in *ex situ* conditions is insufficiently and poorly documented. Some countries have fully computerised documentation systems and reasonably complete accession data. These include most European Countries, the USA, Canada, Japan, China, India, Brazil, Ethiopia, and Kenya. Many countries report partial or ongoing computerisation of documentation systems. In countries with decentralised *ex situ* germplasm collections, such as several in Western Europe, databases are maintained by the individual institutes and centralised documentation systems do not exist. Many countries simply lack information on the accessions in their own collections.<sup>61</sup> In general, at the global level, documentation of *in situ* conservation activities and resources is lacking. A total of 55 countries report the need for improvements in documentation and information systems, and many emphasise the need for integrated, compatible systems which allow for easy exchange of information.

76. Characterization information generally concerns strongly heritable characters which are independent of the environment, e.g., taxonomic characters, in contrast to evaluation information which relates mainly to traits of agronomic importance which are often highly environment specific. Characterization of accessions provides essential information for genebank management. Some characterization data can also be useful to plant breeders.

77. As Figure 4.4 shows, the degree to which collections have been characterised is widely variable. One study from 1984 estimated that 80% of accessions in world collections are not characterised and only 1% have been extensively evaluated.<sup>62</sup> Another study indicated that some 80-95% of the world's germplasm collections lack characterization or evaluation data.<sup>63</sup> However, these overall statistics may differ significantly between species. For example, it has been found that precise data on place of collection (latitude and longitude) were available for 78% of the world's *ex situ* holdings of wild *Triticum* and *Aegilops* species.<sup>64</sup>

78. Ethnobotanical information on the history and local uses of germplasm is usually scant and not available in the database systems.

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<sup>60</sup> The total number of accessions being stored in *ex situ* genebanks is approximately 6 million. Some of these are active or working collections; base collections may contain perhaps 3 million accessions. There is some duplication amongst accessions in base collections. As indicated above, the percentage of unique accessions might be estimated at about 35%. Assuming this applies to base collections, the number of unique accessions might therefore be of the order of one million. If, on the other hand it is assumed that the 35% of all 6 million accessions are unique, the number of unique accessions might be estimated to be of about 2 million. This might be considered to be an upper limit. Taking the estimate of the proportion of accessions that need regeneration as 48%, it can be estimated that the backlog requiring regeneration amounts to between 0.5 and 1 million accessions. Some of these accessions however, may already have lost their viability or genetic integrity, or be from populations where re-collecting might be more cost-effective than regeneration.

<sup>61</sup> Globally, only 48 countries report that passport data is available for all the accessions (approximately 2 million) in their collections. The data, however, may be minimal.

<sup>62</sup> Peeters JP and Williams JT (1984) Toward better use of genebanks with special reference to information. Plant Genetic Resources Newsletter 60:22-32.

<sup>63</sup> Plucknett DL, Smith NJH, Williams JT and Anishetty NM (1987) Gene Banks and the World's Food. Princeton, New Jersey, USA: Princeton University Press.

<sup>64</sup> Hodgkin T (1991) The core collection concept. In: Crop network-new concepts for genetic resources management. International Crop Network series 4. Rome, Italy: IBPGR.

### Botanic Gardens

79. There are approximately 1 500 botanic gardens in the world, of which nearly 700 have germplasm collections. More than 60% of the botanic gardens are situated in Europe, the USA and the countries of the former USSR. Slightly over 10% of all botanic gardens are privately owned.

80. Botanic gardens conserve some ornamental species, wild relatives of crops, medicinal, and forest species. More than 115 also conserve germplasm of cultivated species including landraces, wild food plants and other non cultivated species which are locally utilised. Because such species are frequently lacking in other *ex situ* germplasm collections, botanic gardens play an important, if sometimes unrecognised, complementary role in *ex situ* conservation systems.

81. Species of importance for medicinal and ornamental purposes are often more fully represented in botanic garden collections than in traditional PGRFA collections. They may therefore fill an important gap in *ex situ* conservation programmes. Figure 4.5 illustrates the involvement of botanic gardens in the conservation of plant genetic resources for food and agriculture. Linkages between these botanic gardens and more crop-oriented genebanks and PGRFA researchers are weak and few gardens are strongly integrated into national or regional efforts related to PGRFA. The need for a comprehensive approach to *ex situ* conservation and the inclusion of botanic gardens and arboreta in such programmes has been emphasised by many countries during the preparatory process for the International Technical Conference.

82. The number of accessions conserved per taxon in botanic gardens usually ranges between one and five. This indicates that, while botanic gardens conserve considerable amounts of inter-species diversity, they conserve very little intra-species genetic diversity. This poses a potential constraint to certain types of utilization.

### Strengthening of Ex Situ Conservation

83. In conclusion, it has become clear that capacities for *ex situ* conservation need to be strengthened in a number of ways. However, it is also widely recognized that the sustainability of conservation efforts depends on maintaining collections in a cost effective manner.<sup>65</sup> Emphasis therefore must be on measures which improve the efficiency of conservation programmes, through rationalisation of efforts, and the use of low-cost conservation methods.<sup>66</sup>

84. In particular, the following measures have been identified as necessary:

- the identification of priorities for filling gaps in collections;<sup>67</sup>
- the development of low-cost conservation technologies, and in particular, of technologies for non-orthodox seeded and vegetatively propagated plants including *in vitro* methods, and cryopreservation;<sup>68</sup>
- the need for a global regeneration effort;<sup>69</sup>
- the need to reduce unnecessary duplication of accessions;<sup>70</sup>

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<sup>65</sup> Sub-regional meeting for East Asia.

<sup>66</sup> Sub-regional meeting for East Asia.

<sup>67</sup> Sub-regional meeting for North America.

<sup>68</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; for Central America, Mexico and Caribbean; and for East Asia.

<sup>69</sup> Agenda 21, Para. 14.57.

<sup>70</sup> Sub-regional meeting for North America; and for East Asia.

- the need to promote efficiency in germplasm management and use (through core collections, better and more accessible information and documentation systems, etc.);<sup>71</sup>
- the need for primary characterization and evaluation to facilitate collaboration with plant breeders and to promote the sustainable use of plant genetic resources.<sup>72</sup>

85. During the preparatory process for the International Technical Conference, a number of sub-regional meetings pointed out the importance of collaboration at national, sub-regional and/or regional, and international levels. This, they noted, might include a sharing of the burden of long-term *ex situ* conservation through the rational organization of base, active and working collections.<sup>73</sup>

86. Synergy could be promoted by developing voluntary options for countries to place materials in secure storage facilities outside their country, without compromising their sovereign rights over such materials.<sup>74</sup> The sub-regional meeting for West and Central Africa, for example, identified the creation of a sub-regional genebank as a high priority.<sup>75</sup> It was suggested that national genebanks give priority to active or working collections, while long-term conservation in base collections might be more effectively carried out at the sub-regional level.<sup>76</sup> International financing might be used to facilitate such rationalisation of activities based on comparative advantages.

Region	Accessions		Genebanks	
	Number	%	Number	%
Africa	353 523	6	124	10
Latin America and Caribbean	642 405	12	227	17
North America	762 061	14	101	8
Asia	1 533 979	28	293	22
Europe	1 934 574	35	496	38
Near East	327 963	6	67	5
<b>Total</b>	<b>5 554 505</b>	<b>100</b>	<b>1 308</b>	<b>100</b>

*Source: Country Reports and WIEWS Database*

<sup>71</sup> Sub-regional meeting for North America.

<sup>72</sup> Sub-regional meeting for North America and regional meeting for Europe.

<sup>73</sup> Sub-regional meeting for East Africa and Indian Ocean Islands; for North America; for West and Central Africa, and for Southern Africa.

<sup>74</sup> Sub-regional meeting for East Asia; for West and Central Africa; for East Africa and the Indian Ocean Islands; and for Southern Africa.

<sup>75</sup> Sub-regional meeting for West and Central Africa.

<sup>76</sup> Sub-regional meeting for West and Central Africa; and for East Africa and the Indian Ocean Islands.



Country and Institute	Accessions	Facilities	Regeneration status
<b>China</b> Institute of Crop Germplasm	300 000	Long term storage; space available	Not yet needed since genebank is only 8 years old
<b>USA</b> National Seed Storage Laboratory	268 000	Long term storage; capacity of 1,000,000 accessions	19% backlog; main constraints are lack of human resources and facilities for regenerating cross pollinated crops
<b>Russia</b> VIR	177 680	No long term facilities	Regeneration is required frequently
<b>Japan</b> NIAR	146 091	Long term facilities	4% backlog; no specific problems reported
<b>India</b> NBPGR	144 109	New genebank being built with capacity of 600,000 accessions	63% backlog; no specific problems reported
<b>Republic of Korea</b> RDA	115 639	Long term facilities Total capacity 200 000 accessions	50% backlog. Main problems are with cross pollinated species.
<b>USA</b> National Small Grain Collection	119 000	Active collection	Not applicable
<b>Canada</b> PGRC	100 000	Long term facilities	No specific problems reported
<b>Germany</b> IPK, Gatersleben	67 000	Long term facilities	Main constraint is staff resources
<b>Brazil</b> CENARGEN	60 000	Long term facilities Capacity for 100000 accessions	64% backlog; main constraints are funds, infrastructure and human resources
<b>Germany</b> FAL, Braunschweig	57 000	Long term facilities	Main constraint is staff resources
<b>Italy</b> Bari	55 806	Long term facilities	No specific problems reported
<b>Ethiopia</b> Biodiversity Institute	54 000	Long term facilities	Main constraints, funds, land and human resources
<b>Hungary</b> Institute for agrobotany	45 833	Long term facilities	No specific problems reported
<b>Poland</b> Plant breeding & acclimatization institute	44 883	Long term facilities	No specific problems reported

*Source: Country Reports*

<b>Genebank</b>	<b>Year established</b>	<b>Accessions</b>	<b>Storage facilities<sup>1</sup></b>	<b>Main crops</b>
Tropical Agricultural Research and Training Center (CATIE)	1976	35 056	LT, MT, IV, F	Cucurbita; Capsicum; Phaseolus; coffee; cocoa
Asian Vegetable Research and Development Center (AVRDC)	1971	37 618	LT, MT, F, IV	tomato; Capsicum; soybean; mung bean
Nordic Gene Bank (NGB)	1979	27 303	LT, MT, F, IV	cereals; fruits & berries; forages; potatoes; vegetables; root crops, oil crops and pulses.
Southern African Development Community-Plant Genetic Resources Centre (SPGRC)	1988	312	LT	Base collections; duplicates of national collections
Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD)			F	Fruit trees

1 : LT = long term, MT = medium term, IV = *in vitro*, F = field

**Source - WIEWS**

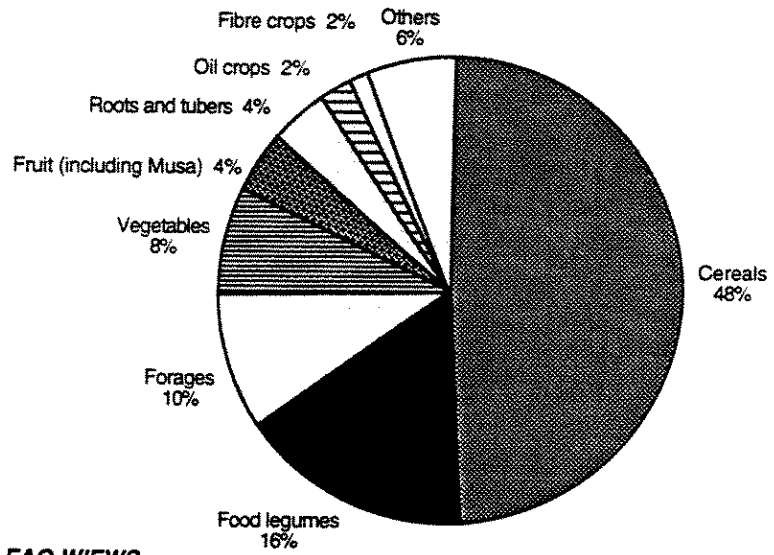
Table 4.4 *Ex situ* storage facilities and extent of duplication of collections in the CGIAR centres

	No. of accessions	Storage facilities	LT Storage capacity (accessions)	Comments	Duplication
ICRISAT	110 374	LT, MT, ST, IV	96 500	Urgent need to speed up process of transferring collections to LT storage. Main constraints: funds & staff levels.	Millet 24% Chickpea 97% Pigeon Pea 22% Groundnut 28% Sorghum 42%
CIAT	70 940	LT, MT, ST, IV, F	100 000	Main constraint is availability of funds. Many accessions have sub-standard numbers of seeds and regeneration is required urgently. For some forage accessions, recollection may be more efficient than regeneration.	Phaseolus 76% Cassava 76%
CIMMYT	112 116	LT, MT, F	108 000	Regeneration of maize and wheat ongoing. Resources lacking for regeneration needs. Active and base storage areas are nearly full*.	Wheat 50% Maize 80%
CIP	13 844	LT, MT, IV, F, Cr	10 000	Potato seed samples not yet regenerated due to resource limitations. Main constraints are financial and human resources.	Potato 100% Sweet potato 93%
ICARDA	109 029	LT, MT, ST, F	70 000	International communication links are poor.	Durum wheat 41% Faba bean 35% Lentil 91% Chickpea 51% Barley 23%
ICRAF		LT, MT**, F	4 freezers**	Possibility of multiplication of seed by NARs, NGOs and farmers, on contract, to be explored.	
IITA	39 765	LT, MT, IV, F	60-70 000	Problems with phytosanitary status of germplasm.	Soybean 47% Yam 15% Cowpea 30% Bamb. groundnut 17% Banana 89% Cassava 36% Rice 42%
ILRI	13 470	LT, MT, IV, F	13 000	Recommends contracting out of regeneration work.	Forage grasses and legumes 74%
IRRI	80 646	LT, MT	108 060	Regeneration research ongoing.	Rice 76%
WARDA	17 440	ST	20 000**	LT storage at IRR! and IITA.	
INIBAP/ IPGRI	1 046	IV, Cr, F		Need for further collecting of <i>Musa</i> genetic diversity	<i>Musa</i> sp. 39%
<b>Total</b>	<b>604 743</b>				

Source: CGIAR-SGRP Genebank Reviews

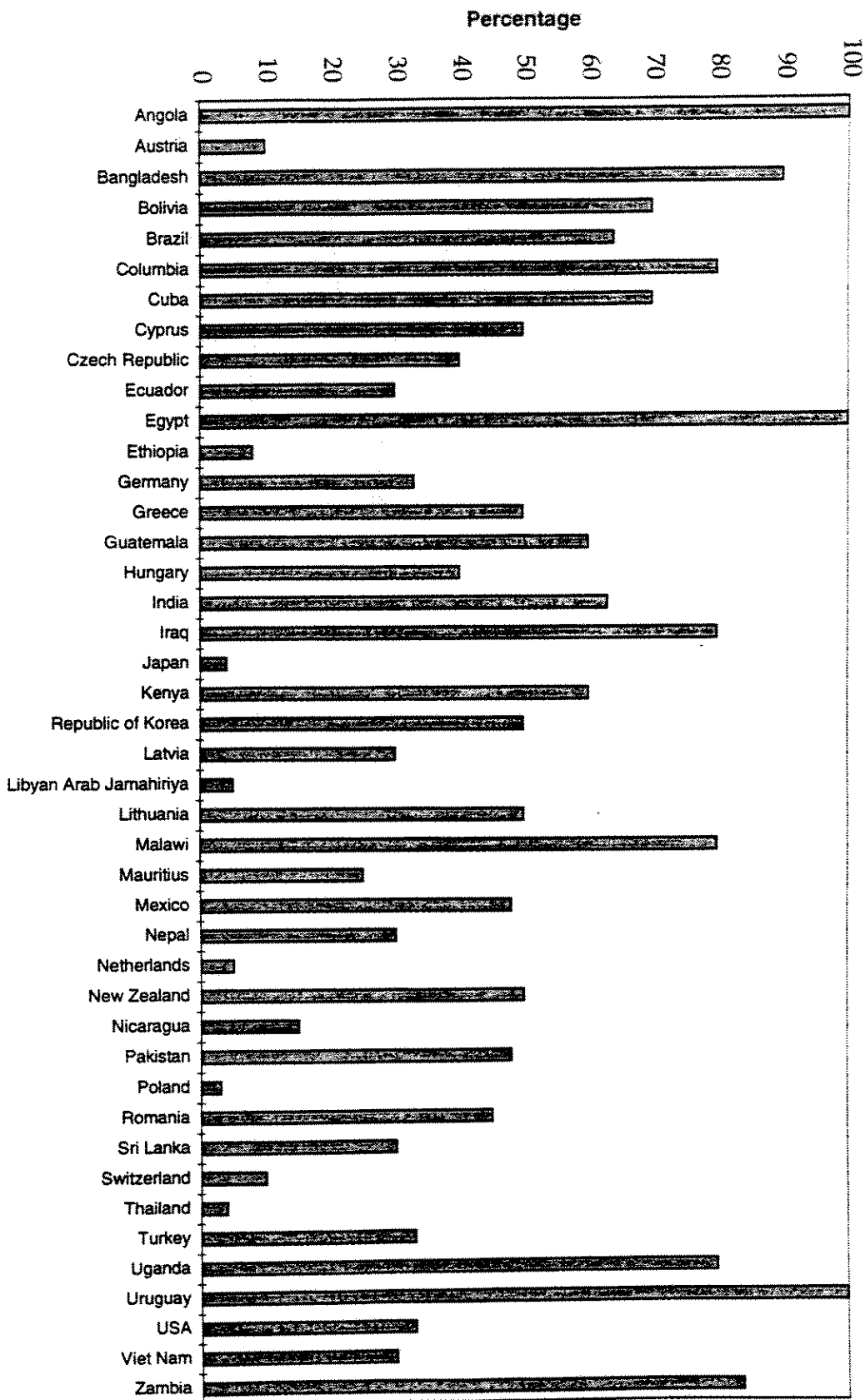
LT: long term; MT: medium term; ST: short term; IV: in vitro; Cr: cryopreservation; F: field  
 \* New facility to be built in 1995-96. \*\*Planned facilities

**Figure 4.1 The Contribution of Major Crop Groups to Total *Ex Situ* Collections**

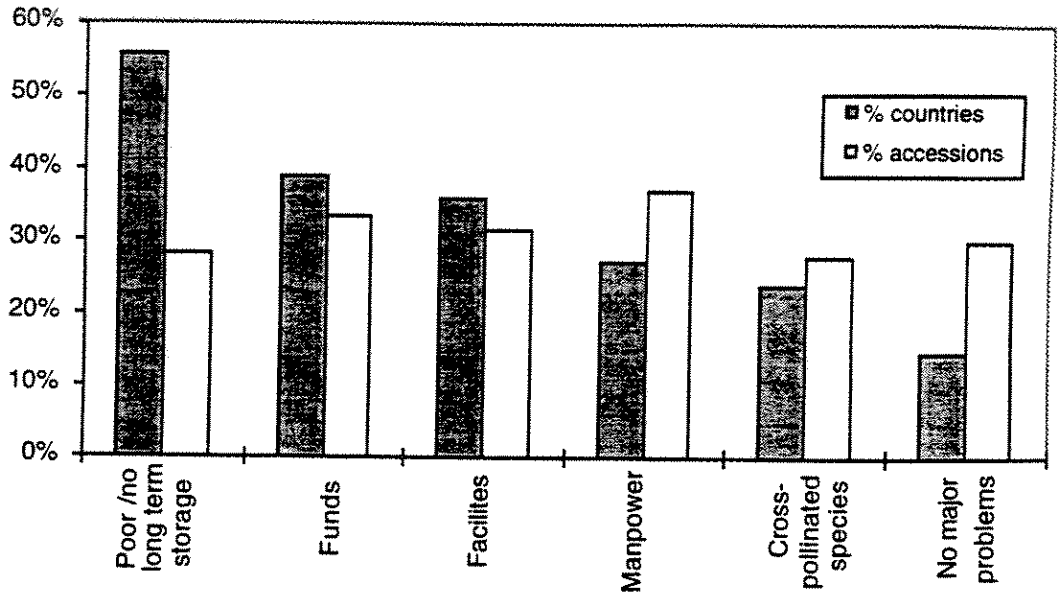


**Source: FAO WIEWS  
database**

**Figure 4.2 Percentage of accessions in national collections needing regeneration**  
**Source: WIEWS Database**

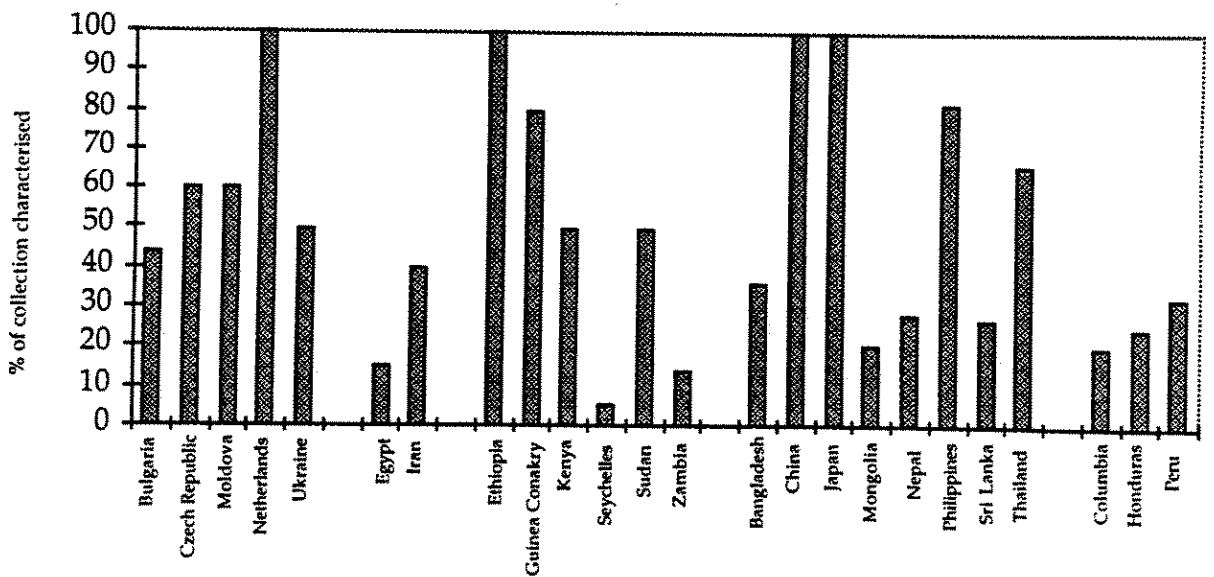


**Figure 4.3 Main Constraints to Regeneration in National Genebanks**  
(Information provided by 95 Countries holding 4 515 793 Accessions)



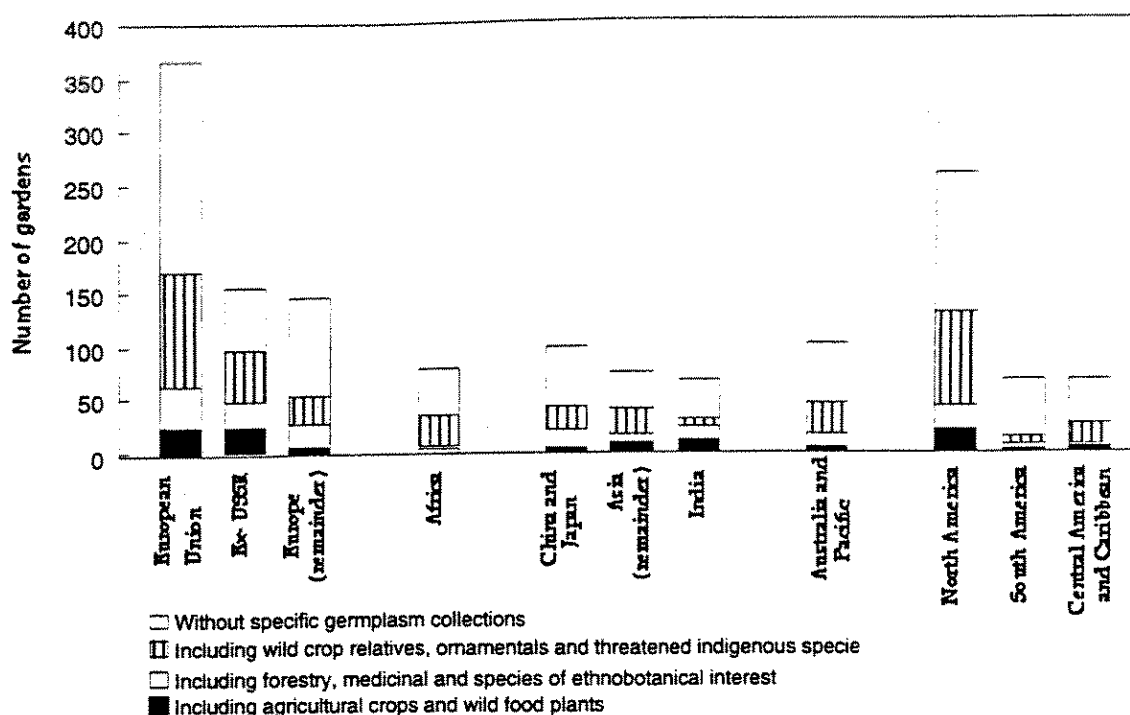
Source: Country Reports

**Figure 4.4 Extent of Characterization of Ex Situ Collections, Selected Examples**



Source : Country Reports

Figure 4.5 Conservation of PGRFA in Botanic Gardens



## Chapter 5 Utilization of Plant Genetic Resources

87. With rising population pressure and reductions in the area of prime land available for agriculture, increases in food production as well as more equitable food distribution will be necessary. There is a pressing need in most countries for better utilization of plant genetic resources (including under-utilised species) through plant breeding. Promoting the utilization of PGRFA can also be a way of contributing to the fair and equitable sharing of benefits derived from these resources.

88. The term "utilization" is used in two different ways:

- direct utilization by farmers and others in agricultural production systems including cropping systems, rangelands, forests and other managed resource areas;
- utilization at an intermediate stage, e.g., utilization by plant breeders and other researchers.

### *Use of PGRFA Conserved in Genebanks*

89. Data is generally not available on how many accessions maintained by genebanks have been used in breeding programmes or have contributed to improved varieties. China reports that only 3-5% of the accessions conserved are presently used in breeding programmes, a rate which, without reflection, might appear to be quite low. However, as base collections exist to provide a long-term repository for potentially useful materials, one would expect the level of "utilization" at any one time to be low. The utilization of a relatively small proportion of a genebank collection can, of course, lead to large benefits, as breeding programmes routinely demonstrate. A distinction must be made, therefore, between low rates of utilization and poor utilization.

90. Numerous obstacles limit the effective use of plant genetic resources, as shown in Table 5.1. Through their Country Reports, countries have identified the following as major constraints to the utilization of germplasm in national genebanks: lack of characterization and evaluation data (cited by 45 countries), lack of documentation and information (42 countries), poor co-ordination of policies at the national level (37 countries), and poor linkages between the

genebank and the users of the germplasm (32 countries). In addition, 20 countries stated that they did not have plant breeding programmes.

#### *Evaluation*

91. Evaluation is important to identify potentially valuable traits in accessions, as well as landraces which could be used directly by farmers. Very little quantitative information was provided by the Country Reports on the state of evaluation of genebank collections. Table 5.2 provides available data from individual countries. Where estimates of the proportions of collections which had been evaluated for agronomic characters were cited, these were often extremely low. Almost every country, in some sense, cited the lack of useful evaluation information as a major bottleneck to increasing the utilization of PGRFA.<sup>77</sup> Several countries identified the need for increased collection and utilization of ethno-botanical and indigenous knowledge associated with PGRFA.<sup>78</sup> Core collections, which contain a maximum percentage of diversity in a sub-set of the whole collection, could play a more important role in enhancing germplasm utilization by making management and screening of collections more efficient and cost effective.<sup>79</sup>

#### *Prebreeding*

92. Prebreeding or germplasm enhancement involves the transfer or introgression of genes and gene combinations from unadapted sources into more usable breeding materials. It can serve to broaden the genetic base of breeding materials.<sup>80</sup> It is a long-term activity, the costs of which are difficult to recoup as the benefits accrue to all breeders. Private sector breeders cannot generally afford to undertake such work. Most public research institutes, universities and research or funding agencies have done prebreeding in the past, but with the withdrawal of the public sector from breeding activity, pre-breeding activities in many countries are now often left unfunded. Prebreeding of several major crops is largely carried out in some of the CGIAR centres. Very few Country Reports mentioned pre-breeding or genetic enhancement as a national breeding activity, though a number called attention to the importance of such work.<sup>81</sup>

#### *Crop improvement programmes*

93. National capacities for crop improvement vary widely and depend upon available technical, human and financial resources. Most countries have government funded programmes for classical plant breeding and in some the private sector is also involved. While a number of countries have initiated crop improvement programmes based on new biotechnologies, not all countries have the capacity to use such technologies.

94. Funding was the constraint cited in the largest number of Country Reports, followed by availability of human resources and lack of suitable facilities. Availability of germplasm was generally not identified as a problem in any of the regions. Figure 5.1 shows constraints to plant breeding, by region, as identified by countries.

95. Plant breeding has been enormously successful in increasing agricultural productivity at the global level. The Green Revolution in the 1960s prompted large increases in yields of rice and wheat. Nonetheless, the success of modern plant breeding has been uneven regionally. The large yield increases in wheat, rice and maize produced in Asia have not been duplicated in

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<sup>77</sup> Numerous Country Reports (including those of about 40 countries that identified evaluation as a unique need).

<sup>78</sup> For example: Brazil, Kenya, Guinea, Sierra Leone, Chile, Venezuela, Indonesia, Malaysia, Germany, Yemen, Ireland and Eritrea.

<sup>79</sup> Sub-regional meeting for the Mediterranean.

<sup>80</sup> Sub-regional meeting for the Mediterranean.

<sup>81</sup> *Inter alia*, Tanzania, Nigeria, Germany, Portugal, Canada.



Africa.<sup>82</sup> Adoption rates of modern varieties have been much lower in physically marginal environments among low-income farmers. Different strategies may be necessary if such farmers are to have access to and benefit from the range of PGRFA available to other farmers.

#### *Participatory plant breeding*

96. Plant breeders and farmers both have comparative advantages which can help define functional divisions of labour in the improvement of PGRFA. Breeders have the advantage of access to a wide range of genetic diversity and the scientific knowledge and methods to work efficiently in the development of improved germplasm. Farmers can select material for their particular environments and for special market requirements. Participatory plant breeding - involving farmers more directly in the breeding process - may increase the success of breeding for complex farming systems in more diverse and marginal environments. Such approaches call on farmers to finish the breeding effort by selecting materials, on farm, according to their own needs. Farmer participation in pearl millet breeding at ICRISAT has produced encouraging results, increasing potential gains from the breeding programme while promoting cost efficiency, according to a review by ICRISAT scientists.<sup>83</sup> The approach offers the potential of promoting wider use of genetic diversity and promoting the management and development of locally adapted genetic resources.

#### *Seed Supply Programmes*

97. Seed production and distribution are today predominantly public sector activities in developing countries, and increasingly private sector activities for the major crops in Europe and North America. Private sector involvement is expected to increase in the future for commercial crops. The scope of the formal seed industry (private or government) is limited in many developing countries, with use of farmer-saved seed and informal farmer-to-farmer seed exchange being the predominant source of supply for many farmers.<sup>84</sup> More than a quarter of all Country Reports - and over half of the Reports from Africa - indicated that poor seed production and distribution systems constrain the dissemination of improved crop varieties (Figure 5.2).

98. Many resource-poor farmers in developing countries - and particularly those in marginal areas - plant genetically heterogeneous crops, to minimise risk of crop failures.<sup>85</sup> Traditional agricultural systems also commonly contain great intra-specific genetic diversity. Legislation and regulations on variety release, seed certification and plant breeders' rights can discourage or fail to encourage within-cultivar genetic variability, indicating the possible need for review of regulatory frameworks for their effects on the conservation and use of PGRFA.<sup>86</sup>

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<sup>82</sup> McCalla AF (1994) Agriculture and Food Needs to 2025: Why We Should Be Concerned. CGIAR Secretariat, World Bank, Washington. (Some limitations on production increases are becoming apparent in Asia, where the Green Revolution was most successful. There are now some troubling signs that the yield increases of the main crops -- wheat and rice -- are slowing).

<sup>83</sup> Weltzien E, Whitaker ML, Anders MM. (1995) "Farmer participation in pearl millet breeding for marginal environments," in Participatory Plant Breeding. Proceedings of a workshop on participatory plant breeding, 26-29 July 1995, Wageningen, The Netherlands. Eyzaguirre P and Iwanaga M (eds.), IPGRI (1996).

<sup>84</sup> Venkatesan V (1994) Seed Systems in Sub-Saharan Africa: Issues and Options, World Bank Discussion Papers, Africa Technical Department Series No. 266.

<sup>85</sup> Clawson DL (1985) Harvest security and intraspecific diversity in traditional tropical agriculture. Economic Botany 39:56-67.

<sup>86</sup> Sub-regional meeting for the Mediterranean.

99. An increased research effort is needed on the potential of genetically heterogeneous crop production whether at the level of intra-species diversity (landraces, mixtures, multilines) or inter-specific diversity (multi and inter-cropping) especially for marginal environments<sup>87</sup>.

**Table 5.1 OBSTACLES TO THE GREATER USE OF PGRFA**

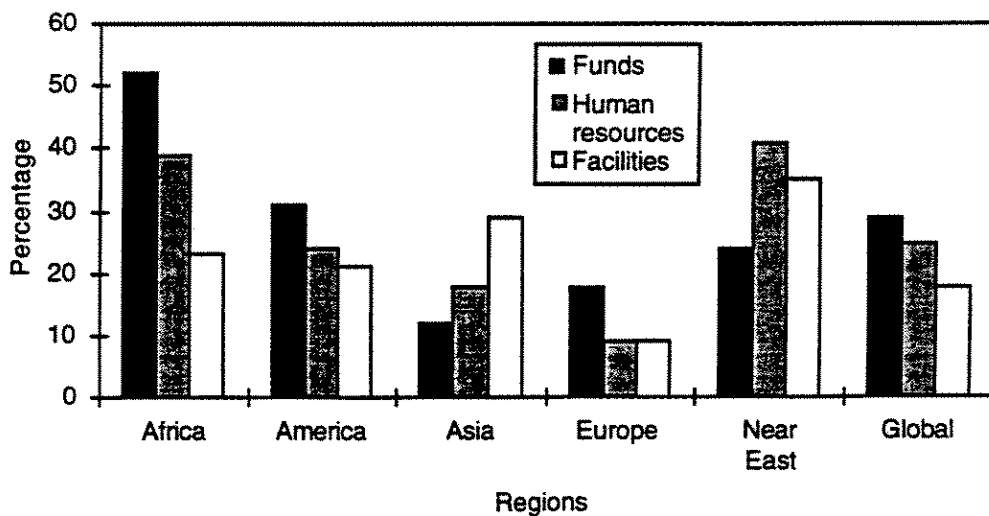
<b>Obstacle</b>	<b>How it might be overcome</b>
lack of information on material existing <i>in situ</i>	<ul style="list-style-type: none"> <li>• surveys and inventories</li> </ul>
bias in material conserved	<ul style="list-style-type: none"> <li>• targeted collecting</li> <li>• develop conservation methodologies for non-orthodox seeded and vegetatively propagated plants</li> </ul>
lack of evaluation / information about conserved material ( <i>ex situ</i> or on farm)	<ul style="list-style-type: none"> <li>• documentation &amp; characterization</li> <li>• evaluation</li> <li>• surveys of traditional knowledge</li> <li>• crop networks</li> </ul>
lack of information about existence of conserved material	<ul style="list-style-type: none"> <li>• information and communication systems</li> <li>• crop networks</li> </ul>
difficulty in accessing collections	<ul style="list-style-type: none"> <li>• rational organization of base, active and working collections</li> <li>• legal arrangements</li> <li>• greater collaboration between genebanks and breeders, <i>inter alia</i> through strong national programmes</li> <li>• documentation and communications systems</li> </ul>
difficulty in handling large collections	<ul style="list-style-type: none"> <li>• documentation systems</li> <li>• core sub-sets</li> <li>• crop networks</li> </ul>
difficulty and expense of introducing genetic diversity into breeders' adapted lines	<ul style="list-style-type: none"> <li>• pre-breeding/ genetic enhancement programmes, including base-broadening</li> </ul>
lack of plant breeding capacity	<ul style="list-style-type: none"> <li>• increased funding and/or training</li> <li>• international collaborative programmes</li> </ul>
unsuitability of improved varieties for marginal environments and/or specific needs of small farmers	<ul style="list-style-type: none"> <li>• decentralised breeding, including participatory approaches</li> </ul>
lack of effective seed production and distribution networks for small farmers	<ul style="list-style-type: none"> <li>• stimulate private sector and informal seed production and distribution networks</li> </ul>
lack of availability of landraces for direct use	<ul style="list-style-type: none"> <li>• evaluation <i>in situ</i> and <i>ex situ</i></li> <li>• provision of landraces by genebanks for multiplication and distribution to farmers</li> </ul>
unsustainable use of wild under-utilised species	<ul style="list-style-type: none"> <li>• develop sustainable management practices</li> </ul>
small range of species addressed	<ul style="list-style-type: none"> <li>• improvement programmes for minor staples and other under-utilised species</li> </ul>
restrictions on variety release, seed distribution	<ul style="list-style-type: none"> <li>• review regulatory framework</li> </ul>
lack of markets	<ul style="list-style-type: none"> <li>• post harvest processing</li> <li>• promote new markets.</li> </ul>

<sup>87</sup> Jiggins J (1990) Crop variety mixtures in marginal environments. International Institute for Environment and Development Gatekeeper Series No. SA19. London: IIED.

Country	% of samples evaluated at least once for some traits	Country	% of samples evaluated at least once for some traits
Iran	5%	Colombia	20%
Egypt	15%	Paraguay	31%
Poland	68%	Korea Republic	40%
Slovak Republic	28%	Mongolia	20%
Samoa	0%	Guinea Conakry	50%
Bangladesh	23%	Eritrea	0%
Nepal	28%	Ethiopia	100%
Morocco	60%	Ukraine	90%
Czech Republic	60%	Seychelles	90%
Cambodia	0%		
Thailand	50%		

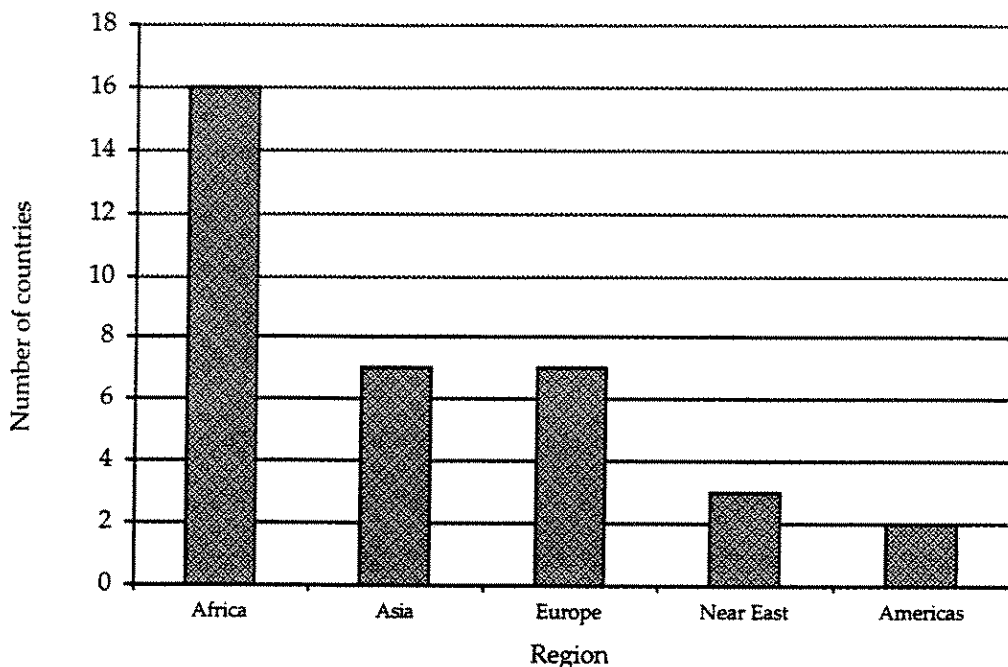
Examples as available from Country Report information

**Figure 5.1 Percentage of Countries Reporting the Lack of Funds, Human Resources and Facilities as a Constraint to Plant Breeding Activities**



Source: Country Reports

**Figure 5.2 Number of Countries Citing Poor Seed Distribution Systems as a Constraint to the Dissemination of Improved Varieties**



Source: Country Reports

## Chapter 6 National Programmes, Training Needs, Policies and Legislation

100. The successful conservation and sustainable utilization of PGRFA involve action by a wide range of people in each country: germplasm curators, breeders, scientists, farmers and their communities, resource area managers, planners, policy makers, and NGOs. Strong planning, evaluation, and coordination mechanisms are needed at the national level to enable all to participate constructively. Fifty-nine countries reported that they had national committees on plant genetic resources. Table 6.1 provides an overview of the purposes and functions of national programmes.

101. National programmes differ in scope and structure, with some being centralised and others being more dispersed in terms of organizational responsibilities.<sup>88</sup> Some countries, *inter alia* Morocco, Indonesia, Malaysia and Costa Rica, rely more on coordinating mechanisms than a formal structure. Finally, some countries lack a national programme of any type. Ten countries indicated in Country Reports that national programmes were under development. Further information on the state of development in national programmes is provided in Table 6.2.

102. Few national programmes have a formal, legal status or enjoy their own line-item in the nation's budget.<sup>89</sup> Short-term budget allocations are the norm for work that is long-term by

<sup>88</sup>In Europe, for example, Austria, France, Germany, Italy, Switzerland, and the UK have more-or-less decentralized systems, with different genebanks having responsibilities for different types of germplasm.

<sup>89</sup>Fewer than one-fifth of the countries mentioned in their Country Report that there were particular line items for PGRFA activities. Of these, a number still cited financial constraints.

nature. Country Reports reveal that even programmes in developed countries sometimes lack financial security and the ability to plan ahead due to budget uncertainties.

103. Frequently, the national focal point responsibilities for PGRFA matters reside with the genebank or specialized institute dealing with conservation of crop genetic resources. Only a fourth of the countries submitting Country Reports indicated that either *in situ* conservation or utilization were included in the scope of their national programme. Based on information supplied in Country Reports, it would appear that the equating of national programmes with national genebanks has been partially responsible for the underdevelopment of functional linkages between conservation and utilization efforts. Genebanks are often isolated institutionally as well as practically from crop improvement programmes. Aid programmes which provide funds for genebanks alone can exacerbate the problem. And managers - many of whom see their mandate purely as one of conservation - frequently complain of the low level of use that is made of the collections. The newly independent states of the former USSR typically have an incomplete PGRFA infrastructure as a result of recent political changes. They may have well developed capacity in breeding, for example, but may not have a genebank or anything more than working collections. Small island states confront the problem of economies of scale in initiating a broad range of essential activities for what may be a relatively small population. Increased regional cooperation was suggested in the sub-regional meetings as one way of addressing such situations.<sup>90</sup>

104. Viewed holistically, national efforts in PGRFA also include the activities of NGOs (including the private sector), universities, farmers and their communities and organizations. Some of these are particularly active in areas in which some governments are not, e.g., *in situ* and on-farm programmes, and commercial breeding and seed production and distribution. A small number of national committees now contain NGO representatives, and there are practical cooperative ventures underway involving NGOs and government programmes in several countries, including the United States and Ethiopia.

#### Training

105. Almost 80% of the Country Reports referred to lack of training as a serious constraint in their national programmes.

106. The University of Birmingham (UK) offers a MSc. degree focusing on PGRFA which is over-subscribed by a wide margin each year. The University of Zambia, the University of the Philippines-Los Banos and perhaps several other universities are in the process of developing PGRFA degree programmes, however, none are fully operational at this time. Lack of capacity - including support for students, proper equipment, and a "critical mass" of instructors - are the major constraints to training at this level, particularly in developing countries.

107. All regions identified certain training needs during the preparatory process for the International Technical Conference, including:

- modules on PGRFA for university courses in the various disciplines;<sup>91</sup>
- advanced and specialized courses, preferably at the regional level, in systematics/taxonomy, population genetics, ecology, ethnobotany, plant breeding, seed production and utilization, germplasm management, and policy;<sup>92</sup>
- integration of PGRFA training in wider academic *curricula* on agriculture, research and development, biology, etc.
- short courses at the regional and national levels, covering topics such as breeding, seed production and distribution, conservation technologies, quarantine, collecting, etc.;<sup>93</sup>

<sup>90</sup> Sub-regional meeting for East Africa and the Indian Ocean Islands.

<sup>91</sup> Sub-regional meetings for West and Central Africa; and for East Africa and the Indian Ocean Islands.

<sup>92</sup> Sub-regional meeting for West and Central Africa.

<sup>93</sup> Sub-regional meeting for Central America and Caribbean; for West and Central Africa.

- training of national programme managers in areas including management and planning, policy development and analysis, and the enhancement of inter-institutional and regional cooperation;<sup>94</sup>
- training for farmers, including women, (e.g., on farm management and improvement of PGRFA), which may be done in cooperation with NGOs.<sup>95</sup>

#### *National Legislation and Policy*

108. In most countries, legislation and policies have often developed piecemeal and in reaction to a particular need or crisis over a number of years. One notable exception is Eritrea, where extensive consultations were held at the community level before development of a national environmental action plan.

109. In general, North American and European countries state that PGRFA in national collections are freely available to all *bona fide* users.<sup>96</sup> The situation regarding access cannot be so clearly summarized in other regions based on information supplied in Country Reports.

110. Many countries have phytosanitary regulations covering import and export of materials. A number of countries, however, have trouble enforcing such regulations.<sup>97</sup> There are a number of regional agreements and associations concerned with this subject. Southeast Asia nations, for example, have an association which regulates the movement of plant materials within the sub-region.

111. Forty countries have laws concerning "plant breeders' rights," thirty of which are members of the International Union for the Protection of New Varieties of Plants (UPOV) under the 1978 Convention. Countries of the Andean Pact have developed their own system, and some countries are also considering joining UPOV. India and the Philippines are considering legislation which may incorporate an element of reward to the providers of genetic resources. Member countries of the World Trade Organization will be obliged in the future, to provide for the protection of plant varieties, either by patents, or an effective *sui generis* system, or a combination thereof.<sup>98</sup>

112. Finally, an appropriate level of public awareness of the importance of PGRFA and of programmes for its conservation and utilization is lacking in virtually all countries. Responsibility for raising public awareness rests at all levels and with all institutions and organizations. Few national programmes have capacity or funds for public awareness activities, a situation which is both a cause and effect of current under-investment in PGRFA. NGOs have made contributions to raising awareness in a number of countries. Most sub-regional meetings stressed the importance of educational and public awareness work.

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<sup>94</sup> Sub-regional meetings for East Asia; Central and West Asia; Country Report: Germany.

<sup>95</sup> Sub-regional meeting for West and Central Africa; Sub-Regional Synthesis Report for Southern Africa.

<sup>96</sup> The recent privatization of agricultural research institutes in some Eastern European countries has cast uncertainty over the continuing free availability of their PGRFA, however.

<sup>97</sup> Botswana, Namibia, Niger, Ecuador, Guatemala and Nicaragua noted difficulties in their Country Reports.

<sup>98</sup> Through the Sub-regional Meeting Report of West and Central Africa, Governments requested assistance in drafting suitable legislation for plant varieties in line with international agreements and national needs.

<b>Table 6.1 National Programmes or Systems on PGRFA</b>					
<p><u>Purposes</u></p> <ul style="list-style-type: none"> <li>• to contribute to national development, food security, sustainable agriculture and the maintenance of biodiversity, through the conservation and utilization of PGRFA</li> <li>• to assess - and address - national needs for PGRFA</li> </ul> <p>(Needs can be met from material conserved in-country, either <i>in situ</i> (including on-farm) or <i>ex situ</i>, and through access to germplasm conserved elsewhere.)</p>					
<p><u>Functions</u></p> <table border="0"> <tr> <td style="vertical-align: top;"> <ul style="list-style-type: none"> <li>• development of national policies and strategies</li> </ul> </td> <td style="vertical-align: top;"> <ul style="list-style-type: none"> <li>• coordination of national activities; involving all stakeholders; promotion of linkages</li> </ul> </td> <td style="vertical-align: top;"> <ul style="list-style-type: none"> <li>• basic building blocks for regional and international collaboration</li> </ul> </td> </tr> </table>			<ul style="list-style-type: none"> <li>• development of national policies and strategies</li> </ul>	<ul style="list-style-type: none"> <li>• coordination of national activities; involving all stakeholders; promotion of linkages</li> </ul>	<ul style="list-style-type: none"> <li>• basic building blocks for regional and international collaboration</li> </ul>
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<p><u>Activities</u></p> <table border="0"> <tr> <td style="vertical-align: top;"> <ul style="list-style-type: none"> <li>• inventories, monitoring, collecting</li> <li>• conservation <i>in situ</i> &amp; <i>ex situ</i></li> <li>• documentation and characterization</li> <li>• evaluation &amp; genetic enhancement</li> <li>• crop improvement</li> <li>• seed/variety distribution &amp; production</li> <li>• dissemination of information</li> </ul> </td> <td style="vertical-align: top;"> <ul style="list-style-type: none"> <li>• training &amp; capacity building</li> <li>• research</li> <li>• fund raising</li> <li>• legislation</li> <li>• regulation of access to, and exchange of, genetic resources</li> <li>• public awareness</li> </ul> </td> <td></td> </tr> </table>			<ul style="list-style-type: none"> <li>• inventories, monitoring, collecting</li> <li>• conservation <i>in situ</i> &amp; <i>ex situ</i></li> <li>• documentation and characterization</li> <li>• evaluation &amp; genetic enhancement</li> <li>• crop improvement</li> <li>• seed/variety distribution &amp; production</li> <li>• dissemination of information</li> </ul>	<ul style="list-style-type: none"> <li>• training &amp; capacity building</li> <li>• research</li> <li>• fund raising</li> <li>• legislation</li> <li>• regulation of access to, and exchange of, genetic resources</li> <li>• public awareness</li> </ul>	
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<p><u>Partners</u></p> <ul style="list-style-type: none"> <li>• ministries and government departments (i.e., agriculture, forestry/natural resources, environment, planning, education/research)</li> <li>• universities and other research and educational institutes</li> <li>• NGOs, farmers' organizations, women's groups</li> <li>• private sector and parastatal companies</li> <li>• regional and international organizations and networks</li> </ul>					
<p>Source: Reports of sub-regional meetings</p>					

<b>Table 6.2 State of development of national PGRFA programmes by sub-region</b>	
<b>Sub-region</b>	<b>State of development of national programmes</b>
Africa - West/Central	Few formal national programmes. National Plant Genetic Resources Centres in Ghana and Nigeria. Lack of funding and official recognition of national committees.
Africa - East/Indian Ocean	Well-developed national programmes in Ethiopia and Kenya. Under development in Uganda and Sudan. Little progress in Burundi, Rwanda and Indian Ocean Islands.
Africa - South	National programmes well developed with impetus provided by SPGRC. However many have strong focus on <i>ex situ</i> conservation only.
America - Central/Caribbean	Few formal national programmes (exceptions Cuba and Honduras). Need for development strongly expressed.
America - North	Well developed formal national programmes.
America - South	Need to develop formal national programmes strongly expressed. Formal programme already exists in Brazil.
Asia - East	Strong national programmes in Japan, China, Republic of Korea. Less developed in DPR Korea and Mongolia.
Asia - South	Well developed, comprehensive national programmes in India, inclusive of plant quarantine. Other countries have need for more coordination and funding.
Asia - South east	Integrated national programmes exist in Thailand and Vietnam and a well developed national PGR network in the Philippines. Coordination approach among institutes in Malaysia and Indonesia.
Pacific	No formal national programmes. Little PGR activity in small island nations. Strong interest and limited activities in some countries, e.g., Papua New Guinea, Solomon Islands.
Europe - East	Most countries have central institute responsible for national programmes. Formal national programmes under development in the Newly Independent States. Baltic states developing collaboration with Nordic Gene Bank.
Europe - West	Formal national programmes exist in most countries. Coordination is important in countries with decentralised <i>ex situ</i> conservation systems. Nordic countries have centralised regional programme - Nordic Gene Bank.
Near East - South and East Mediterranean	Lack of coordination is a bottleneck in many countries. Good coordination exists in Morocco. WANANET has played important role in strengthening national committees.
Near East - West/Central Asia	Well developed programmes in Turkey, Islamic Republic of Iran and Pakistan. WANANET has played important role in strengthening national committees. Central Asian countries still need to develop more complete national programmes.

Source: Country Reports



## Chapter 7 Regional and International Efforts

### *Collaboration at the Regional and Sub-regional Level*

113. During the preparatory process for the International Technical Conference, the interdependency between countries for PGRFA was acknowledged<sup>99</sup> and the value of sub-regional and regional collaboration was recognized.<sup>100</sup> The following were identified as objectives for regional or sub-regional collaboration:

- to strengthen national PGRFA programmes<sup>101</sup>
- to avoid unnecessary duplication of activities<sup>102</sup>
- to share burdens of conservation and to promote exchange of genetic material<sup>103</sup>
- to develop efficient systems of documentation and communication<sup>104</sup>
- to promote exchange of information, experience and technology<sup>105</sup>
- to promote collaborative research<sup>106</sup>
- to promote evaluation and utilization of conserved material<sup>107</sup>
- to coordinate research, including the programmes of the IARCs<sup>108</sup>
- to identify and promote collaboration in training and capacity<sup>109</sup>
- to formulate proposals for regional projects.<sup>110</sup>

114. Many of the objectives identified in the preparatory process can be promoted through existing<sup>111</sup> or new regional or sub-regional programmes. In particular the need for databases providing information on the *in situ* and *ex situ* germplasm available in the region, for sub-

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<sup>99</sup> Sub-regional meeting for North America, and for Europe. See also Chapter 1.

<sup>100</sup> Sub-regional meetings for West and Central Africa; for East Asia; for Central America, Mexico and Caribbean; and for South America.

<sup>101</sup> Sub-regional meeting for West and Central Africa.

<sup>102</sup> Sub-regional meetings for West and Central Africa; for East Africa and the Indian Ocean Islands; and for East Asia.

<sup>103</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; for West and Central Africa; and for Southern Africa.

<sup>104</sup> Sub-regional meeting for West and Central Africa.

<sup>105</sup> Sub-regional meeting for Central and West Asia; and for Central America, Mexico and Caribbean.

<sup>106</sup> Sub-regional meeting for Central and West Asia.

<sup>107</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; for Central and West Asia; and for Southern Africa.

<sup>108</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; for Southern Africa; and for Central America, Mexico and Caribbean.

<sup>109</sup> Sub-regional meetings for East Africa and the Indian Ocean Islands; and for Central America, Mexico and Caribbean.

<sup>110</sup> Sub-regional meeting for Central and West Asia.

<sup>111</sup> Sub-regional meetings for the Mediterranean; and for East Africa and the Indian Ocean Islands.

regional newsletters, and for translation of information in the languages of the region was highlighted.<sup>112</sup>

115. Functioning networks are established for Europe, the Near East, Southern Africa, South-East Asia and Latin America, although some need strengthening (Table 7.1). Networks for South and East Asia have been established recently and need to be developed. There is a need to establish new networks, in the context of existing regional research organizations where appropriate, for Central Asia, West and Central Africa, East Africa and the Indian Ocean Islands, the Pacific and the Caribbean. There is also a need to strengthen links between South and Southeast Asia, and between the two sides of Mediterranean. Only sound national programmes, however, can provide the basis for successful and sustainable collaboration.

116. Many crop-specific networks and working groups operate under the auspices of regional or sub-regional networks (Table 7.1). Other networks operate at an international or inter-regional level. These networks bring together different types of specialists to set priorities for further work on the conservation and utilization of genetic resources of a particular crop or crop group. There is a need to strengthen or establish networks and working groups for priority crops.<sup>113</sup> FAO has over the years developed a number of crop-related networks to promote a coordinated approach to identifying, evaluating and conserving the genetic variability of selected crop species. These include the International Mushroom Germplasm Conservation Networks; the Olive Genetic Variability Conservation Network; the International Network on Cactus Pear; the Mediterranean and Inter-American Citrus Networks; the Inter-regional Cooperative Network on Nuts; the Mediterranean Fruit-tree Network in Asia, and the Network of Traditional Crops of Southern Africa.

117. Countries in some regions have established central regional genebanks including: the Nordic Genebank, the SADC Plant Genetic Resources Centre and CATIE. Additionally, some international organizations hold germplasm collections in particular crops. The Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD), for example, holds an important field genebank collection of fruit trees. As noted in Chapter 4, a number of sub-regional meetings in the preparatory process called attention to the need and opportunities for cooperation in the *ex situ* conservation of PGRFA. The development or designation of regional or sub-regional genebanks might provide alternative options to the building of national genebanks, particularly for conserving duplicate base collections.<sup>114</sup>

118. The need for countries of regions or sub-regions to share the burden, or costs, of conservation was mentioned at several of the preparatory meetings.<sup>115</sup> Countries also recognized the important role of the International Network of Base Collections under the Auspices of FAO in this regard.<sup>116</sup> Twelve CGIAR Centres joined the Network in September 1994; one country has since joined, and 30 more have expressed a willingness to join.

#### *Programmes of the CGIAR*

119. Virtually all countries mentioned collaboration with the International Agricultural Research Centres of the Consultative Group on International Agricultural Research (CGIAR) in their County Reports. While the conservation and improvement of the mandate crops is

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<sup>112</sup> Sub-regional meeting for West and Central Africa.

<sup>113</sup> Sub-regional meetings for Southern Africa; and for North America.

<sup>114</sup> Sub-regional meetings for the Mediterranean; for Central and West Asia; and for South Asia. One donor country provided data on the recent costs of building genebank facilities in several developing countries. In addition, estimates of costs were obtained from a private company experienced in genebank construction, and one country provided a proposal for the construction of a national genebank. Based on these figures (which differed substantially), constructing a long-term facility for each country currently lacking one, could cost from US\$ 40 million to over US\$ 1 billion (exclusive of annual operating expenses).

<sup>115</sup> Sub-regional meetings for the Mediterranean; for West and Central Africa; and for East Africa and the Indian Ocean Islands.

<sup>116</sup> Sub-regional meetings. for West and Central Africa and for Southern Africa

organized primarily on a global basis (Table 7.2), some other CGIAR activities are organized on an eco-regional basis. Many countries proposed that the research agenda of the CGIAR centres be broadened to encompass a wider range of species.<sup>117</sup> In addition to the crop-specific networks operating on a regional and sub-regional basis, there are a number of global crop-specific networks.

#### *FAO and the Global System*

120. Since 1983, FAO has been developing a comprehensive Global System for the Conservation and Utilisation of Plant Genetic Resources for Food and Agriculture.<sup>118</sup> The current status of the components of the Global System is indicated in Table 7.3. UNCED's Agenda 21 requested that the Global System be strengthened, and, in this context, the Commission has agreed that the preparation of the first Report on the State of the World's Plant Genetic Resources, and the Global Plan of Action, as two of its key elements, will be a major contribution in this task. The strengthening of the legal, financial and institutional mechanisms involved is being addressed in the parallel process of the revision of the International Undertaking, through negotiations in the Commission on Genetic Resources for Food and Agriculture.

121. Besides providing the Secretariat for the Commission on Genetic Resources for Food and Agriculture, and support to the other components of the Global System, the Regular Programme of FAO provides support for national capacity building in plant genetic resources conservation, plant breeding, seed production and distribution, and related legal and policy issues. The FAO's Field Programme has also carried out a large number of projects and programmes in developing countries, many with components related to the conservation and utilization of plant genetic resources. Many of these are financed through the United Nations Development Programme (UNDP).

#### *Other international organisations involved in PGRFA activities*

122. Other intergovernmental and international organizations include the United Nations Environment Programme (UNEP), the United Nations Conference on Trade and Development (UNCTAD), the United Nations Industrial Development Organization (UNIDO), the Commonwealth Science Council, the World Conservation Union (IUCN), the International Fund for Agricultural Development (IFAD), the World Bank, the Regional Development Banks, and the Global Environmental Facility.

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<sup>117</sup> Sub-regional meeting for Southern Africa.

<sup>118</sup> Article 7 of the FAO International Undertaking states that "the present international arrangements, being carried out under the auspices of FAO and other organisations in the United Nations System, by national and regional institutions, and institutions supported by the CGIAR, in particular the IBPGR, for the exploration, collection, conservation, maintenance, evaluation, documentation, exchange and use of plant genetic resources will be further developed and, where necessary, complemented, in order to develop a global system ...".

**Table 7.1 Regional and sub-regional PGRFA networks**

Region	Sub-region	Existing PGRFA networks	Status and comments	Crop specific networks
Europe	West. Europe	ECP/GR	Very well-developed network; self-financing	EUFORGEN: for forest genetic resources. ESCORENA: for flax, olive, soybean and sub-tropical fruits. MESFIN: Fruits for Mediterranean region.
	East. Europe		Most countries of the region are members	
Near East	S/E Mediterran.	WANANET	Well-developed network; Links with ECP/GR need to be strengthened (eg in Mediterranean)	Network activities involving institutions from Eur., N. Afr. and W. Asia on pistachio, rocket, oregano, hulled wheat. MESFIN: Fruits for Mediterranean region.
	West Asia		Except for CIS countries of Central Asia, most countries of the region are members	
	Central Asia		Network or sub-network required for CIS countries of Central Asia	
Africa SS	S. Africa	SPGRC	Well-developed network; all countries of the region are members; Partially self financed.	SACCAR coordinates several networks for improvement of millet, groundnut, pigeonpea, cowpea, rootcrops, wheat, maize, bean, and regional vegetables
	Central Africa	—	Network for Central & Western Africa proposed in context of existing organizations	CORAF includes some crop networks for peanuts, cotton, casava, maize and rice
	West. Africa	—	Need for closer cooperation identified	Same as for Central Africa
	East Africa			PRAPACE: for potato and sweet potato; EARRNET: root crops; EARSMN: sorghum and millet; EARCORBE: banana; RESAPAC: bean; AFRENA: agro-forestry
	Indian Ocean			
Asia / Pacific	South Asia	S.As./PGRN	Formal network is being established	—  APINMAP information on medicinal and aromatic plants, SAPPRAD: for potato and sweet potato; UPWARD: potato  Carried out in the context of other cooperative arrangements: PRAP for sweet potato, SPC: root crops
	SE Asia	RECSEA	Well developed network, needs more financing	
	East Asia	E.As./PGRN	Formal network is being established	
	Pacific	Pacific PGRN	Formal network is being initiated	
Americas	South America	TROPIGEN REDARFIT Procisur-RF	Well-established networks, ago-ecologically based, all countries members of one or more	Bean: PROFIZA (Andean zone); Potato: PRACIPA (Andean zone), PROCIPA; Cacao: PROCACAO; coffee: PROMECAFE. IAGNET (Citrus);
	C. Am & Mexico	REMERFI	Well-established network	PROFIJOL for bean; PRECODEPA for potato. IAGNET (Citrus);
	Caribbean	CMPGR	New network, mostly focused on anglophone countries; need to integrate with hispanophone and francophone countries	PRECODEPA network for potato
	North America	—	Good bilateral links.	

<b>Centre</b>	<b>Principal Crops/category of crops</b>	<b>Scope</b>
CIAT	Five cultivated <i>Phaseolus</i> spp., genus <i>Manihot</i> , tropical forage species	
CIMMYT	Maize, hexaploid wheat and <i>triticale</i>	Entire gene pools; close cooperation with ICARDA on wheat
CIP	Potato, sweet potato and several minor Andean root and tuber crops.	Entire gene pools
ICARDA	Barley, lentil, faba bean, durum wheat, bread wheat, kabuli chickpea	Entire gene pools; for barley global responsibility may be shared with other institutions through a network
INIBAP (part of IPGRI)	Banana and plantain spp.	Entire <i>Musa</i> gene pool
ICRISAT	Sorghum, pearl millet, chickpea, pigeonpea, groundnut, minor millet	Entire gene pools; for minor millets only base collection responsibility
IITA	Cassava, maize, plantain, cowpea, soybean, rice, yam, agroforestry spp.	Entire gene pool responsibility for <i>Vigna unguiculata</i> and <i>Dioscorea</i> spp. Germplasm of other species also conserved
IRRI	Rice	Entire gene pool of <i>Oryza</i> and related genera
WARDA	West African rice ( <i>Oryza sativa</i> and <i>O. glaberrima</i> )	Entire genetic variability of its mandate crops with respect to collecting, conservation and documentation
ICRAF	No specific mandate species; more than 2000 multipurpose trees	Plan to concentrate on 20 species; gene pool concept not so important for agroforestry species; cooperation with other Centres (CIAT, CIFOR, ICRISAT, IITA, ILCA, IPGRI and IRRI)
ILRI	No mandate crops; species useful for livestock feed	Gene pool concept does not really apply; responsibility for collecting, conservation and documentation accepted
CIFOR	Forestry species	
IPGRI (for INIBAP, see above)	All crop species, particularly crops of regional importance and crops which are not mandate crops of other centres	Co-ordination of system-wide research strategy; facilitating documentation, information & training, operating in close cooperation with other centres and national agricultural research systems

Source: based on Working Document AGR/TAC: IAR/92/24

<b>Table 7.3 Status of the Global System for the Conservation and Utilization of PGRFA</b>		
<u>Component(s)</u>	<u>Function</u>	<u>Status</u>
Commission on Genetic Resources for Food and Agriculture	intergovernmental global forum	Established 1983 as the Commission on Plant Genetic Resources; 138 members (August 1995); six sessions plus one extraordinary session held; Scope broadened in 1995 to include other sectors of agrobiodiversity, starting with livestock. A Panel of Experts on Forest Gene Resources is a technical advisory body to FAO.
International Undertaking on Plant Genetic Resources	non-binding agreement to assure conservation, use and availability of PGRFA	Adopted 1983; 110 countries adhere; annexes agreed in 1989 (including Farmers' Rights) and 1991. Currently under revision including for harmonisation with the CBD, development of agreements on access, and the realization of Farmers' Rights.
International Fund for PGR	to provide a channel for support & promotion of sustainable PGR conservation & use at a world level	Not yet operational. Principle agreed by FAO Conference; GPA will be useful in determining requirements for Fund.
Global Plan of Action for the conservation and sustainable utilization of PGRFA	to rationalise & improve the international efforts for the conservation and use of PGRFA	First Plan expected to be adopted by International Technical Conference on PGR, in June 1996
Report on the State of World's PGRFA	to report on all aspects of conservation & use of PGRFA to identify gaps, constraints & emergencies	First Report to be considered by International Technical Conference on PGR. Expected to be adopted by ITC in June 1996
World Information & Early Warning System	to collect & disseminate data on PGRFA & related technologies; identifying hazards to genetic diversity	Information system established, including records of <i>ex situ</i> collections in 135 countries. Early Warning System at planning stage.
Network of <i>Ex Situ</i> Collections under the Auspices of FAO	to facilitate access to <i>ex situ</i> collections on fair and equitable terms	Established with collections of 12 IARCs (agreement signed in October 1994); 31 countries expressed their willingness to include their collections; one has signed agreement. International standards for genebanks agreed.
Network of <i>in situ</i> areas	to promote conservation of landraces, crop wild relatives and forest genetic resources	No significant progress.
Code of Conduct for germplasm collection and utilization	to promote conservation including collection and use of PGR in ways that respect environment and local traditions and culture	Adopted by FAO conference in 1993.
Code of Conduct on Biotechnology	to promote safe practices, and promote the transfer of appropriate technologies	Consideration of draft code suspended pending revision of International Undertaking.
Crop-Related Networks	to promote sustainable and optimal utilization of germplasm	Nine inter-regional or international networks established.
Total number of countries and regional economic integration organizations which have become members of the CGRFA and/or adhered to the Undertaking is 149.		
Updated from FAO Programme Evaluation Report 1993-4		

## Chapter 8 Access and Benefit Sharing

123. The facilitation of access to PGRFA, under appropriate mechanisms, and the sharing of benefits derived from their utilization, are two of the goals of both the International Undertaking and the Convention on Biological Diversity.<sup>119</sup> The International Undertaking is currently being revised with the support of the Conference of the Parties to the Convention, through negotiations between countries in the Commission on Genetic Resources for Food and Agriculture, in order to harmonise it with the Convention, and for consideration of the issues of access to plant genetic resources for food and agriculture and the realization of Farmers' Rights.<sup>120</sup>

### Access

124. The fact that the agricultural systems of virtually all countries are highly dependent on non-indigenous species is testimony to the wide dispersal of materials from the earliest days of agriculture itself. More than 1 300 genebanks hold over 6 million accessions (many of which are duplicates), largely as a result of the wide degree of access to PGRFA historically.

125. Until recently, PGRFA have been regarded as the "common heritage of mankind". Collecting has usually been freely allowed. Recently a voluntary International Code of Conduct for collecting and transfer of germplasm, based on the principle of national sovereignty over plant genetic resources, has been agreed at FAO. The Code sets out standards and principles to be observed by countries that adhere to it, and proposes a number of mechanisms for benefit sharing. The Convention on Biological Diversity provides for access to plant genetic resources on mutually-agreed terms, based on the prior informed consent of the country providing the resources.

126. Many of the largest genebanks in the world, including those in Europe, North America and in the CGIAR system, have policies of unrestricted availability to *bona fide* users.<sup>121</sup> Table 8.1 shows the number of materials distributed by the CGIAR Centres, by type and destination. A number of genebanks in developing countries maintain similar policies regarding access, though scarce resources for multiplication and processing may limit or delay availability.<sup>122</sup> Political disagreements between countries on matters unrelated to PGRFA have sometimes made access problematic. In some cases, countries appear as a matter of policy to have restricted access to unique and potentially valuable undeveloped germplasm.<sup>123</sup> However, the great majority of unique PGRFA accessions in *ex situ* collections has been generally available for plant breeding and research purposes. The FAO Seed Exchange Unit has, over the years, distributed over 0.5 million seed and planting material samples of improved varieties and landraces.

127. Breeders' lines, special genetic stocks, and other materials under development are generally not freely available, however. And information about and access to PGRFA held by private companies is typically restricted. Use of materials protected by patents or plant breeders' rights is subject to certain conditions.

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<sup>119</sup> The Convention has three primary objectives: conservation, sustainable utilization, and the fair and equitable sharing of benefits. It also recognizes as intermediate objectives, the facilitation of appropriate access to genetic resources and related information and technologies, and of appropriate financing, taking into account rights over all such resources.

<sup>120</sup> Resolution 3/91; definition of Farmers' Rights.

<sup>121</sup> During the period 1992 - 1994, the United States, for example, distributed a total of 116 897 samples to 126 countries.

<sup>122</sup> For example, China indicated the need for funds for the multiplication of seeds, so as to allow exchange of genetic resources. Chinese Academy of Agricultural Sciences: "Proposals for Drafting the Global Action Plan on Plant Genetic Resources (communication to FAO Secretariat, 10 October 1994).

<sup>123</sup> Coffee and black pepper are frequently cited examples.

128. The Convention on Biological Diversity provides for access to be granted on "mutually agreed terms." Such terms might be agreed upon bilaterally or multilaterally. For agricultural biodiversity, the Conference of the Parties has declared its support for the process engaged in the FAO Commission on Genetic Resources for Food and Agriculture for the revision of the International Undertaking<sup>124</sup>.

#### *Benefit Sharing*

129. The contribution of farmer varieties and wild relatives to the modern varieties being grown in many countries today is clearly evident. A number of crops, such as sugar cane, tomatoes, and tobacco, could not be grown on any substantial commercial scale, were it not for the crucial contribution made by wild relatives of those crops to disease resistance.<sup>125</sup> However, no comprehensive agreed estimates exist of the value of genetic material so utilised. Similarly no estimate of the incremental economic value of improved varieties exists.

130. Economic analysis, however, supports the view that many of those engaged in conserving and developing PGRFA, such as many farmers and their communities, do not receive benefits proportionate to the value of the germplasm originating from their fields<sup>126</sup>. This has been recognized by countries through the FAO resolution on Farmers' Rights which calls for farmers' and their communities to participate fully in the benefits derived from the use of plant genetic resources.

131. During the preparatory process for the International Technical Conference, countries stressed the importance of the utilization of PGRFA as the chief means of increasing the value of the material and reaping benefits from it.

132. Currently many countries, and many of their farmers, benefit from the development of new varieties, based on the use of PGRFA, including those developed from improved genetic material supplied by the International Agricultural Research Centres. However, as noted in this Report, some farmers, particularly those who operate in economically marginal areas, often do not benefit substantially from these materials. These tend to be the farmers and communities most involved in conserving, developing, and making available PGRFA of value to formal plant breeding. Based on the findings of this report, the Global Plan of Action proposes a number of activities designed to benefit these farmers in particular.

133. It was not possible to determine the total amount of funds transferred bilaterally or through multilateral mechanisms for the purpose of conserving, developing and using PGRFA. The total annual budget of the CGIAR, for example, is approximately \$300 million. However, figures such as this cannot easily be used as an indicator of benefit sharing, if only because substantial benefits also accrue to the donor countries.

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<sup>124</sup> Decision 11/15 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indonesia, 6-17 November 1995.

<sup>125</sup> Methodological questions concerning economic valuation of PGRFA are explored in Chapter 9.

<sup>126</sup> CPGR/95/8-Supp, Sixth Session of the Commission on Genetic Resources: "Revision of the International Undertaking on Plant Genetic Resources. Analysis of Some Technical, Economic and Legal Aspects for Consideration in Stage II: Access to Plant Genetic Resources and Farmers' Rights".



Table 8.1 Germplasm samples distributed by CGIAR centres, by sector over the period 1992-94, and by number and percentage of accessions

	Other International Agricultural Research Centres		Developing Country National Agricultural Research System		Developed Country National Agricultural Research System		Private Sector		Total
	No.	%	No.	%	No.	%	No.	%	No.
<b>CIAT</b>									
Phaseolus	4 268	77	737	13	488	9	23	0	5 516
Manihot	91	22	201	48	117	28	10	2	419
Forage legumes	1 697	60	609	22	435	15	73	3	2 814
Total	6 056	69	1 547	18	1 040	12	106	1	8 749
<b>CIMMYT</b>									
Maize	2 618	54	451	9	1 598	33	185	4	4 852
Wheat	3 212	60	1 838	35	276	5	0	0	5 326
Total	5 830	57	2 289	22	1 874	18	185	2	10 178
<b>WARDA</b>									
Total	1 372	49	1 400	50	0	0	8	0	2 780
<b>ICARDA</b>									
Total	10 333	41	10 034	40	4 624	18	14	0	25 005
<b>CIP*</b>									
Potato	-	-	1 823	93	142	7	-	-	1 965
Sweet potato	-	-	484	95	27	5	-	-	511
Total	-	-	2 307	100	169	100	-	-	2 476
<b>IITA</b>									
Total	3 988	54	2 576	35	810	11	27	0	7 401
<b>ICRISAT</b>									
Total	24 473	56	17 773	40	302	1	1 438	3	43 986
<b>IRRI</b>									
Total	15 453	71	3 458	16	666	12	91	0	21 668
<b>ILRI</b>									
Total	94	14	359	53	67	10	152	23	672
<b>INIBAP**</b>									
Total	11	3	236	64	124	33	0	0	371
<b>TOTAL</b>	<b>67 505</b>	<b>55</b>	<b>41 620</b>	<b>34</b>	<b>11 609</b>	<b>9</b>	<b>1 869</b>	<b>2</b>	<b>123 093</b>

Source: CGIAR - SGRP Genebank Reviews

\* Data not reported for other IARCs or the private sector.

\*\*INIBAP has sent 478 accessions (58%) to CIRAD principally for virus indexing.

## Chapter 9 The State of the Art

134. This section presents a succinct summary of the major scientific, technological and other methodologies and tools for the conservation and utilization of plant genetic resources. For more specific and technical information relating to any of the topics the references cited indicate some of the most comprehensive reviews that were available in the scientific literature at the time of drafting this document.

### *Methods for analysing and assessing genetic diversity, erosion and vulnerability*

135. Diversity can be analysed at the intra- and inter-specific levels. Diversity can also be studied at other organizational levels, from ecosystems through to cellular, sub-cellular and molecular levels. There are numerous methods available to measure the extent of genetic variation between different plants or populations. Employment of a particular methodology will vary according to the type of information required (Table 9.1).

(i) Morphology-based methods analyse the differences in observable traits (phenotypes) between individual plants. These methods are relatively cheap and are the basis for the characterization of plant accessions in genebanks.

(ii) Molecular methods analyse the differences between either proteins or DNA of plants.<sup>127</sup> There are a wide variety of molecular techniques available with new techniques becoming available all the time.<sup>128</sup> Newer methods generally require more sophisticated equipment and supplies.

136. At the ecosystem level, taxonomic expertise is essential for surveying the diversity of species in a region and the establishment of species inventories which map their geographic range. For many under-utilised crops and wild food plants, such surveys are an essential prerequisite to further studies of the diversity within particular species.<sup>129</sup> There is a need to increase scientific capacity in the area of taxonomy in many countries, particularly in developing countries.<sup>130</sup> Some current initiatives, such as BioNET-International, seek to strengthen the taxonomic capability of developing countries to help inventory their resources effectively.<sup>131</sup>

137. Analyses of plant genetic resources diversity based on such methods can help to:

- identify areas of high genetic diversity;<sup>132</sup>
- determine collecting priorities and sampling strategies;<sup>133</sup>

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<sup>127</sup> Avise JC (1994) *Molecular Markers, Natural History and Evolution*. 1st edn. Chapman & Hall, New York, pp511.; Hillis DM and Moritz C (1990) *Molecular Systematics*, 1st edn. Sinauer Associates, Inc., Sunderland MA.

<sup>128</sup> Westman AL and Kresovich S (in press) Use of molecular marker techniques for description of plant genetic variation. Commonwealth Agricultural Bureau.

<sup>129</sup> Prance GT (1995) Systematics, conservation and sustainable development. *Biodiversity and Conservation* 4:490-500.

<sup>130</sup> Eshbaugh WH (1995) Systematics Agenda 2000: A historical perspective. *Biodiversity and Conservation* 4:455-462; Mc Neeley JA (1995) Keep all the pieces: Systematics 2000 and world conservation. *Biodiversity and Conservation* 4:510-519.

<sup>131</sup> Jones T (1995) Down in the woods they have no names - BioNET - INTERNATIONAL. Strengthening systematics in developing countries. *Biodiversity and Conservation* 4:501-509.

<sup>132</sup> Hamrick JL & Godt MJ (1990) Allozyme diversity in plant species; in Brown, Clegg, Kahler, Weir (Eds.) *Plant Population Genetics, Breeding and Genetic Resources*.

<sup>133</sup> Schoen DJ and Brown AHD (1991) Intraspecific variation in population gene diversity and effective population size correlates with the mating system. *Proc. Natl. Acad. Sci USA* 88:4494-97.

- guide designation of *in situ* or on farm conservation areas;<sup>134</sup>
- monitor genetic erosion<sup>135</sup> or vulnerability;<sup>136</sup>
- guide the management of *ex situ* collections;<sup>137</sup>
- maximise the genetic diversity chosen for core collections;<sup>138</sup>
- compare the agronomically useful regions of the genomes of different crops;<sup>139</sup>
- define the identity of improved varieties or other plant genetic resources;<sup>140</sup>
- monitor the movement of plant genetic resources.<sup>141</sup>

138. While most of these methods measure genetic diversity, they are not usually applied to measuring genetic utility to food and agriculture. To measure the utility of particular plant accessions to agriculture they have to be screened (evaluated) for desirable agronomic characteristics. Some diversity which is useful to food and agriculture can also be identified through the use of surveys of indigenous and traditional knowledge.

139. Effective technology transfer of many of the more sophisticated techniques may be more difficult to those countries which at present lack the necessary infrastructure, trained personnel and resources to maintain the techniques or apply them.<sup>142</sup> Such transfers may be more suitable to regional centres of excellence which are funded sufficiently to support the techniques and apply them to problems of regional significance.<sup>143</sup>

#### *Methods for Ex situ conservation*

140. Methodologies and guidelines for collecting representative samples of genetic diversity have been established for many crops and are increasingly applied in collecting missions.<sup>144</sup>

<sup>134</sup> Bonierbale M, Beebe S, Tohme J and Jones P (1995) Molecular genetic techniques in relation to sampling strategies and the development of core collections. IPGRI Workshop on Molecular genetic Techniques for Plant Genetic Resources, 9-11 October, 1995.

<sup>135</sup> Robert T, Lespinasse R, Pernes J and Sarr A (1991) Gametophytic competition as influencing gene flow between wild and cultivated forms of pearl millet (*Pennisetum typhoides*). *Genome* 34:195-200.

<sup>136</sup> Adams M W (1977) "An estimation of homogeneity in crop plants, with special reference to genetic vulnerability in the dry bean, *Phaseolus vulgaris* L. *Euphytica*, 26:665-679.

<sup>137</sup> Kresovich S, McFerson JR and Westman AL (1995) Using molecular markers in genebanks. IPGRI Workshop on Molecular genetic Techniques for Plant Genetic Resources, 9-11 October, 1995.

<sup>138</sup> Gepts P (1995) Genetic markers and core collections. In: Hodgkin T, Brown AHD, Van Hintum TJL and Morales EAV (eds.) *Core Collections of Plant Genetic Resources*, John Wiley & Sons: UK.

<sup>139</sup> Paterson AH, Lin Y-R, Li Z, Schertz KF, Doebley JF, Pinson SRM, Liu S-C, Stansel JW and Irvine JE (1995) Convergent domestication of cereal crops by independent mutations at corresponding genetic loci. *Nature* 269:1714-1718.

<sup>140</sup> Lee D, Reeves JC and Cooke RJ (1995) The use of DNA-based markers for distinctiveness, uniformity and stability testing in oilseed rape and barley. UPOV Working Group on Biochemical and Molecular Techniques and DNA Profiling in Particular, UPOV Paper BMT/3/4.

<sup>141</sup> Hardon JJ, Vosman B and Van Hintum Th.JL (1994) Identifying genetic resources and their origin: The capabilities and limitations of modern biochemical and legal systems. FAO: Rome, CPGR Background Paper No. 4, November 1994.

<sup>142</sup> Aman RA (1995) A comparative assessment of molecular techniques employed in genetic diversity studies and their suitability in resources limited settings. IPGRI Workshop: Molecular Genetic Techniques for Plant Genetic Resources, 9-11 October, 1995.

<sup>143</sup> Komen J and Persley G (1993) *Agricultural Biotechnology in Developing Countries: A Cross Country Review*. Intermediary Biotechnology Service Research Report 2, The Hague: ISNAR..

<sup>144</sup> Porceddu E and Damania AB (1992) Sampling variation in genetic resources of seed crops: a review. *Genetic Resources and Crop Evolution* 39: 39-49.

New methods for the *in vitro* collecting of vegetatively propagated species or recalcitrant species are also being established.<sup>145</sup> A comprehensive technical manual on collecting plant genetic diversity has recently been published which details the many technical and practical considerations that should be taken into account by plant collectors.<sup>146</sup>

141. There are a number of methods for germplasm storage which differ according to the purpose of storage, the storage behaviour of the species and the available resources (Table 9.3). Seeds of many species can be dried<sup>147</sup> and maintained in a viable condition at sub-zero temperatures and low humidity for many years.<sup>148</sup> This is the most convenient form for long term storage of many plant species with so called orthodox seeds. Crops with orthodox seeds include all the major cereals (such as maize, wheat and rice), the onion family, carrots, beets, papaya, pepper, chickpea, cucumber, the squashes, soybean, cotton, sunflower, lentil, tomato, various beans, eggplant, spinach and all the brassicas. In 1994, FAO and the International Plant Genetic Resources Institute (IPGRI) published genebank standards for the storage of orthodox species which provide useful guidelines for seed condition, seed health, accession size, temperature, humidity, viability monitoring, regeneration and other factors associated with active and base collection storage of orthodox seeds.<sup>149</sup>

142. The seeds of some species cannot be dried and stored for long periods at low temperature and humidity. Such species are called recalcitrant species. Table 9.2 provides a listing of some of these species. Some success has been achieved in extending the storage periods for some of these species,<sup>150</sup> but further work in this area is still needed. IPGRI has recently produced an extensive review of the storage behaviour of 7 000 plant species.<sup>151</sup> While species producing non-orthodox seeds can be conserved *in situ*, it may not be possible to maintain the genetic diversity of the species through *in situ* conservation alone. Many large tree species produce non-orthodox seeds and their size precludes the preservation of more than just a few specimens.

143. The approach to storage may also depend on the biology of the species and the choice of plant organs to be conserved and regenerated. Many crop species which are important in tropical countries are vegetatively propagated (sweet potato, cassava, yam) and are normally conserved in field genebanks. Living collections of selected populations remain the most relevant and utilised conservation method for most forestry and agroforestry species. *In vitro* methodologies are now being developed for the conservation of some crop species as a complement to risky field genebank storage.<sup>152</sup> During the last 15 years, *in vitro* culture techniques have been developed for more than 1 000 plant species. There are many stages in the *in vitro* conservation of any species: discrete procedures are required for tissue culture, storage

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145 Sinha GC (1981) Gene pool sampling in tree crops. In: Mehra KL, Arora RK and Wadhim SR (eds.) Plant Exploration and Collection, NBPGR Sci Monograph No 3, New Delhi.

146 Guarino L, Rao VR and Reid R (1995) Collecting Plant Genetic Diversity: Technical Guidelines, London: CAB International.

147 Delouche JC (1980) Preceptos para el almacenamiento de semillas, Mimeographed. CIAT, Colombia.

148 Orthodox seeds have been defined as: "Seeds for which the viability period increases in a logarithmic manner as one reduces the storage temperature and the moisture content of the same": Roberts EH (1973) Predicting the storage life of seeds, Seed Science and Technology, 1: 499-514. See also, Ellis RH, Hong TD and Roberts EH (1985) Handbook of Seed Technology for Genebanks. Vol I. Principles and Methodology. Rome, IBPGR.

149 FAO/IPGRI (1994) Genebank Standards, FAO: Rome.

150 Ellis RE, Hong T and Roberts EH (1990) An intermediate category of seed storage behaviour? I. coffee. J. Exper. Botany 41:1167-1174.

151 Hong TD, Linington S and Ellis RH (1996) Compendium of information on seed storage behaviour. IPGRI:Rome (in press).

152 Villalobos VM and Engelmann F (1995) *Ex situ* conservation of plant germplasm using biotechnology. Rome: FAO, unpublished.

and successful regeneration, prior to transfer to soils. All of these procedures will require significant research before they can be routinely applied in genebanks. Successful *in vitro* conservation of plantain, banana, cassava,<sup>153</sup> yam,<sup>154</sup> potato,<sup>155</sup> strawberry,<sup>156</sup> sweet potato,<sup>157</sup> and *Allium* spp.<sup>158</sup> have been reported. However, it is notable that as of 1994, fewer than 40 000 accessions had been conserved by *in vitro* techniques worldwide.<sup>159</sup> This may reflect the fact that the routine use of *in vitro* techniques requires specialized equipment, trained staff, and secure electricity supplies, and these requirements limit the extent to which many genebanks apply tissue culture techniques. FAO and IPGRI are currently developing standards for *in vitro*, and field genebank, conservation.

144. There is a need for further research to extend the range of species that can practically be stored in this way and to effectively transfer such technology to the countries where it is required. *In vitro* technologies are one of the more "transferable" biotechnologies, requiring, at the basic level, relatively little sophisticated equipment. They can serve a number of purposes including mass propagation of clonal planting material (micropropagation) and virus elimination as well as germplasm storage. Newer conservation technologies are being developed such as cryopreservation,<sup>160</sup> pollen storage, synthetic seeds<sup>161</sup> and ultradry seed storage,<sup>162</sup> but are still mainly in the research rather than application phase.

145. It has been proposed that DNA "libraries" could be used to conserve total genomic information of a species.<sup>163</sup> However total genomic information is not the same as total genetic diversity and the agricultural utility of this approach is limited because: (i) the genotype is separated from the phenotype, (ii) only single genes identified as useful can be used via genetic engineering, and (iii) each library is expensive to construct and can represent only one sample. The principal utility of DNA libraries is for the isolation of useful genes and not as an alternative conservation strategy.

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153 Chavez R, Roca WM and Williams JT (1987) IBPGR-CIAT collaborative project on a pilot *in vitro* active genebank. FAO/IBPGR PGR NL 71:11-13.

154 Melaurie B, Pungu O, Dumont R and Trouslot M-F (1993) The creation of an *in vitro* germplasm collection of yam (*Dioscorea* spp.) for genetic resources preservation. *Euphytica* 65:113-122.

155 Dodds JH, Huaman Z and Lizarraga R (1991) Potato germplasm conservation. In: *In vitro* Methods for Conservation of Plant Genetic Resources. Dodds JH (ed.) London: Chapman and Hall 93-109.

156 Withers LA (1991) Crop strategies for roots and tubers: Potato a model for refinement, Yam - a problem for development. in ATSAF/IBPGR Workshop on Conservation of plant Genetic Resources. Becker, B (ed.) , Bonn. ATSAF/IBPGR.

157 Kuo CG (1991) Conservation and distribution of sweet potato germplasm. In: *In vitro* Methods for Conservation of Plant Genetic Resources. Dodds JH (ed.) London: Chapman and Hall.

158 Novak FJ (1990) *Allium* tissue cultures. In: Onion and Allied Crops. Rabinovitch JL and Brewster JL (eds.) Florida: CRC Press Inc.

159 CPGR-Ex1/94/5 Annex: Survey of existing data on ex situ collections of plant genetic resources for food and agriculture. CPGR document, 1994.

160 Withers LA (1990) Cryopreservation of plant cells. *Biol. J. Linnean Society* 43: 31-42.

161 Senaratna T and McKersey (1989) Artificial seeds for germplasm preservation, exchange and crop improvement. *Diversity* 2/3:44.

162 Hong TD and Ellis RH (1996). A protocol to determine seed storage behaviour. IPGRI Publication; Tao K-L, Zheng G-H and Cheng H-Y (1995) An overview of ultradry seed storage for germplasm conservation. FAO: Rome.

163 Matlick JS, Ablett EM and Edmonson DL (1992) The gene library-preservation and analysis of genetic diversity in Australasia. In: Conservation of Plant Genes. DNA Banking and *in vitro* Biotechnologies, Adams RP and Adams JE (eds.) San Diego, USA: Academic Press. 15-35.

146. Regeneration is an area of genebank management which tends to be neglected, particularly in budgeting priorities.<sup>164</sup> Accessions should be regenerated in order to replenish stocks which have been depleted due to high demand for samples or through loss in viability. It should be carried out only when necessary to limit genetic changes (genetic drift or shift) in the accessions due to environmental selection during the process; genetic drift can also occur if sufficiently large populations are not grown out.<sup>165</sup> The complexity and cost of maintaining the genetic integrity of accessions of a crop during regeneration depends on the reproductive biology of the species.<sup>166</sup> For instance, it is more difficult and costly to maintain the genetic integrity of cross pollinated crops than self-pollinated crops during regeneration.<sup>167</sup> The complexity and expense<sup>168</sup> are higher for species which are insect pollinated.<sup>169</sup> The reproductive biology of a large number of crops (including the wild relatives of major crops and many under-utilised or minor crops) is not yet sufficiently understood, making the development of regeneration procedures for these crops quite difficult. This is a matter requiring further research.<sup>170</sup> FAO and IPGRI are currently developing guidelines for regeneration.

147. Genetic resources are of little use to plant breeders or genebank managers unless the material is accompanied by adequate information. At a minimum, passport data should be gathered on each accession at the time of collection. Passport data includes such information as country of origin, location of collection site, species name, local names, etc. This information is recorded by the collector of the accession at the collection site. Extensive guidelines for gathering and recording passport data in the field have recently been published by IPGRI.<sup>171</sup>

148. Characterization data are descriptors for characters that are highly heritable, that can be seen easily by the eye, and are expressed in all environments. Such data describe the attributes of the species sampled, including plant height, leaf morphology, flower colour, number of seeds per pod, etc. It is essential information for the genebank curator to distinguish between samples in the collection. To facilitate and standardise the characterization of variants of different crop species, IPGRI has published extensive Descriptor Lists for many crop species. Other descriptor lists have been published by COMECON and UPOV. Such descriptors generally constitute the characterization data that is important for PGRFA management and use. Individual genebanks will use such lists, as appropriate, often adding to or deleting particular descriptors that are not deemed to be relevant to their situation.

149. Many agronomic traits that are required by breeders are too complex genetically to be screened for in the preliminary characterization of germplasm accessions. This data is usually

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<sup>164</sup> It is worth noting that "multiplication" and "regeneration" are different terms: multiplication is for supplying seed samples from an active collection and replenishing the active collection stocks to meet demands from users; regeneration is to maintain seed sample viability in storage.

<sup>165</sup> The problems of genetic change during regeneration are particularly relevant to the management of base collections and have been reviewed in depth elsewhere. See for instance: Breese EL (1989) *Regeneration and Multiplication of Germplasm Resources in Seed Genebanks: The Scientific Background*. Rome: IBPGR.

<sup>166</sup> Frywell PA (1957) Mode of reproduction of higher plants. *Botanical Rev.* 23:235-230.

<sup>167</sup> Porceddu E and Jenkins G (eds.) *Seed Regeneration of Cross-Pollinated Species*. AA Balkema: Rotterdam.

<sup>168</sup> The USDA estimates that regeneration costs can vary between \$50 to \$500 per accession depending on whether the accession is self pollinated or insect cross pollinated respectively. However such costs do vary regionally depending on labour costs and other factors, for instance it is estimated that it may cost US \$700 to regenerate a cabbage accession in the USA while in China it might cost \$15 to regenerate the same accession.

<sup>169</sup> Free JB (1970) *Insect pollination of crops*. Academic Press: New York.

<sup>170</sup> For vegetatively propagated crops, while the genetic integrity during clonal regeneration is not a major problem, disease transmission from generation to generation and the cost of constant maintenance of plant material are major problems.

<sup>171</sup> Moss H and Guarino L (1995) *Gathering and recording data in the field*. In: Guarino L, Rao VR and Reid R (eds.) (1995) *Collecting Plant Genetic Diversity: Technical Guidelines*, London: CAB International.

revealed at the stage of evaluation of germplasm for useful agronomic traits, many of which may be subject to strong genotype by environment (G X E) interactions and hence be site specific. However, the evaluation of germplasm for useful characteristics is generally a stage where the most value is added to plant genetic resources collections because information only then becomes available as to whether the ecotype contains genes of utility to breeders and agriculture in general and whether such utility is site specific or not.

150. Unfortunately, most genebanks have incomplete passport and characterization data for their accessions. Only rarely is evaluation information available in a user friendly form. This situation is caused in part by genebanks not requiring users to return evaluation data for subsequent use by others.

#### *In situ conservation*

151. There are a number of established techniques and strategies for the *in situ* conservation of plant genetic resources, particularly in relation to wild species such as forest tree species. The development of *in situ* conservation strategies requires ecogeographic or agroecological surveys, as a means to identify and target specific PGRFA or ecosystems for conservation.<sup>172</sup> Categories for the assessment of the threat to particular wild plant species have been established by IUCN.<sup>173</sup> In many countries such criteria have been used in developing legislation for the protection of threatened wild species. However such criteria are not intended, nor currently suitable, for maintaining the levels of intra-specific diversity generally required for PGRFA conservation.

152. At the ecosystem level, *in situ* conservation is generally associated with the establishment of protected areas. IUCN classifies protected areas into six categories according to broad management objectives and has recently prepared a set of Guidelines for Protected Areas Management Categories.<sup>174</sup> Many existing protected areas contain PGRFA, but conservation of these resources is often inadvertent. Indeed, the effectiveness of protected areas for conserving genetic diversity has been questioned due to minimal inventories and the lack of consideration of inter or intra-species diversity.<sup>175</sup> To address these shortcomings, the concept of genetic reserves has been proposed, but it has never been widely implemented.<sup>176</sup>

153. More recent strategies for protected area management take account of the need to link environmental protection with human development.<sup>177</sup> Many protected areas support large populations of residents who are currently excluded from effective participation in the decision making processes regarding the management of the protected areas.<sup>178</sup> The United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserves explicitly include consideration of the socio-economic development needs of inhabitants in designated reserves, and some such reserves have also included PGRFA within their management

<sup>172</sup> Maxted N., van slagaren M.W. & Rihan JR (1995) Ecogeographic surveys. In "Collecting Plant Genetic Diversity Technical guidelines." Ed. L. Guarino, V. Ramanatha Rao & R. Reid. CAB International.

<sup>173</sup> IUCN (1994) IUCN Red List Categories, IUCN: Gland Switzerland.

<sup>174</sup> IUCN (1994) Guidelines for Protected Area Management Categories. CNPPA with the assistance of WCMC. IUCN, Gland, Switzerland and Cambridge, UK.

<sup>175</sup> di Castri F and Younes T (1990) Fonction de la biodiversité au sein de l'écosystème. Compte rendu résumé d'une réunion de travail de l'U.I.S.B - SCOPE, 29-30 juin 1989, Washington) Acta Oecologica 11:429-444.; IBPGR (1985) Ecogeographical surveying and *in situ* conservation of crop relatives. Report of an IBPGR Task Force, 30 July-1 August 1984, Washington DC. IBPGR Secretariat, Rome.

<sup>176</sup> Jain SK (1975) Genetic Reserves. pp. 379-398. In: Crop Genetic Resources for Today and Tomorrow. Frankel OH and Hawkes JG (eds.) New York: Cambridge University Press.

<sup>177</sup> Halfpeter G (1994) Putting the biosphere reserve concept into practice: the Mexican experience. In: Integrating Conservation, Development and Research (in press) UNESCO, Parthenion Publishing, London, UK.

<sup>178</sup> Pimbert MP and Pretty JN (1995) Parks, People and Professionals: Putting "Participation Into Protected Area Management", UNRISD Discussion Paper DP 57.

objectives.<sup>179</sup> However the level of effective participation open to communities in designated areas, in decision making and other planning functions has been widely questioned.<sup>180</sup>

154. There are few coordinated programmes of on farm conservation, and therefore as of yet no clear typology of methods.<sup>181</sup> The methods required are often site specific and multidisciplinary in approach. Innovative extension methods<sup>182</sup> (e.g., Participatory Rural Appraisal) supported by technical expertise in seed selection, improvement and production may be required, in concert with appropriate incentive structures.

*Methods for utilization of PGRFA through plant breeding*

155. Plant breeding involves the four fundamental steps of goal setting, generating new genetic combinations, selection, and cultivar release.<sup>183</sup> The ultimate goal of plant breeding is to develop genotypes with superior performance under cultivation by farmers.<sup>184</sup> In formal plant breeding, testing involves a series of trials on different sites over several seasons in which the new varieties are compared with existing varieties. The breeding methods which are chosen are usually dependent on the goals of the improvement programme, which are normally demand-driven in relation to the needs of farmers and consumers.

156. There are two main approaches to crop improvement using exotic genetic material: introgression and incorporation (base-broadening).<sup>185</sup> A variety of plant breeding and biotechnological techniques, which often differ in technical complexity and cost, may be used in crop improvement (Figure 9.1).

157. Introgression is the introduction of specific traits from exotic germplasm into breeders' adapted material through repeated backcrossing over a number of generations. This can be extremely difficult when undesirable genes are linked to the agronomic gene of interest. Recently the advent of molecular genetic maps for many crop species (Table 9.4) has allowed the development of introgression methods based on molecular marker assisted selection.<sup>186</sup> These techniques can reduce the number of generations and hence the time necessary to introduce specific traits. Unfortunately, the current cost of such technologies is prohibitive for many breeding programmes in developed countries and most breeding programmes in developing countries.<sup>187</sup>

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<sup>179</sup> Robertson J (1992) Biosphere reserves: Relations with natural World Heritage sites. *Parks* 3:29-34.

<sup>180</sup> Ghimere K and Pimbert MP (1996) Social change and conservation. UNRISD and Earthscan:UK (in press).

<sup>181</sup> Worede, M. (1992) The role of Ethiopian farmers in the conservation and utilization of crop genetic resources. First Int. Crop Sci. Congress, Ames, Iowa; Altieri MA, Merick LC and Anderson MK (1987) Peasant agriculture and the conservation of crop and wild plant genetic resources. *Conservation Biology* 1:49-58.; Brush SB (1991) Farmer conservation of New World crops: the case of Andean potatoes. *Diversity* 7:75-79.

<sup>182</sup> Chambers R (1994) Challenging the professions: Frontiers for rural development. Intermediate Technology: UK.

<sup>183</sup> Simmonds NW (1979) Principles of crop improvement. Longman: UK, pp 408.; Stalker HT and Murphy JP (1991) Plant Breeding in the 1990s. CAB Int:UK.

<sup>184</sup> Allard RW (1990) Future directions in plant population genetics, evolution and breeding: In: Brown AHD, Kahler AL and Weir BS (Eds) Plant Population Genetics, Breeding and Genetic Resources. Sinauer Associates, Inc: Sunderland.

<sup>185</sup> Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biol. Rev.* 68: 539-562.

<sup>186</sup> Mazur BJ and Tingey SV (1995) Genetic mapping and introgression of genes of agronomic importance. *Current Opinion in Biotechnology* 6:175-182.

<sup>187</sup> Lande R (1991) marker assisted selection in relation to traditional methods of plant breeding. In: Stalker HT and Murphy JP (1991) Plant Breeding in the 1990s. CAB International: UK.



158. Sometimes the desired exotic genes are available in a different species (e.g., a wild relative) which, due to incompatibility between the species, cannot be used in a conventional breeding programme.<sup>188</sup> Biotechnological methods are now increasingly available to facilitate such wide crosses thus allowing the introduction of the desired genes. These techniques have been widely used for crossing related wild species with wheat and other crops.<sup>189</sup> Wide crossing is time consuming and expensive and warrants further research and international cooperation between researchers.<sup>190</sup>

159. The potential of genetic engineering lies in its ability to increase the gene pool available for use in agricultural crops.<sup>191</sup> Not only can single plant genes for agronomic traits be transferred, but also previously inaccessible genes from virtually any species, whether plant, animal or bacteria. Plant genetic transformation describes the transfer of specific genetic material from any species into a plant genome.<sup>192</sup> Since the first transgenic plants of tobacco<sup>193</sup> were produced in 1984 it has now become possible genetically to transform an ever-expanding range of plant species.<sup>194</sup> Other recent developments in transgenic plant technology include the genetic transformation of the chloroplast genome<sup>195</sup> allowing higher levels of gene products to be obtained, and the development of antisense<sup>196</sup> and gene silencing<sup>197</sup> techniques to "turn off" undesirable genes whose DNA (deoxyribonucleic acid) sequences are known.

160. Many useful transgenic phenotypes have been developed using genes from other plant species.<sup>198</sup> Techniques for identifying and isolating desirable genes from plants are currently more labour-intensive than gene transfer techniques, but are under constant improvement.<sup>199</sup> Non-plant sources of genes can also be used through genetic engineering.<sup>200</sup> However, one disadvantage is that current genetic engineering techniques are limited to the transfer of individual genes or small regions of genomes (mainly qualitative traits). Thus, for the foreseeable

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<sup>188</sup> Stalker HT (1980) Utilization of wild species for crop improvement. *Adv. Agron.* 33:111-147.

<sup>189</sup> Baum M, Laguda ES and Appels R (1992) Wide crosses in cereals. *Annu. Rev. Plant Physiol. Mol. Biol.* 43:117-143.

<sup>190</sup> Duvick D (1989) The romance of plant breeding. *Stadler Genetics Symposium.* 19: 39-54.

<sup>191</sup> Flavell RB (1995) Plant biotechnology R & D - the next ten years. *Trends in Biotechnology* 13:313-319.

<sup>192</sup> Walden R and Wingender R (1995) Gene-transfer and plant regeneration techniques. *Trends in Biotechnology* 13:324-331.

<sup>193</sup> Horsch R, Fraley R, Rogers S, Sanders P, Lloyd A and Hoffmann W (1984) Inheritance of functional foreign genes in plants. *Science* 223:496; De Block M, Herrera-Estrella L, Van Montagu M, Schell P and Zambryski P (1984) Expression of foreign gene in regenerated plants and their progeny. *EMBO Journal* 3:1681-1689.

<sup>194</sup> Schmidt K. (1995) "Whatever happened to the gene revolution" *New Scientist*, January 7th:21-25.

<sup>195</sup> Svab Z. and Maliga P. (1993) High frequency plastid transformation in tobacco by selection for a chimeric *aadA* gene. *Proc. Natl. Acad. Sci. USA*, 90:913-917.

<sup>196</sup> Hamilton AJ, Lycett GW and Grierson D (1990) Antisense gene that inhibits synthesis of the hormone ethylene in transgenic plants. *Nature* 346:284-287.

<sup>197</sup> Jorgensen R (1991) Silencing of plant genes by homologous transgenes. *AgBiotech News and Information* 4:265-273.

<sup>198</sup> Hemming D. (1994) Conference Reports: 4th International Congress of Plant Molecular Biology. *AgBiotech News and Information* 6:217-230.

<sup>199</sup> Michelmore, RW. 1995. Isolation of disease resistance genes from crop plants. *Current Opinion Biotechnology* 6: 145-152.

<sup>200</sup> Knauf VC (1995) Transgenic approaches for obtaining new products from plants. *Current Opinion in Biotechnology* 6:165-170.

future, conventional breeding techniques will be necessary for the transfer of the majority of agronomic traits which are controlled by many genes (quantitative or polygenic traits).<sup>201</sup>

161. While introgression is a useful method for introducing specific traits into a breeding population, sometimes a comprehensive broadening of the genetic base is warranted when new genetic variability for polygenic traits is needed. This involves crossing diverse genotypes and then repeatedly selecting from the resulting populations over a large number of generations in the target environment(s). This is known as *recurrent selection*.<sup>202</sup> The final population might be used directly in the breeding programme, or first crossed with other locally adapted material. In forest tree breeding, methods such as the multiple population breeding system, which couple conservation and breeding, have been developed to combine genetic production gains with the maintenance of the adaptive potential of the tree species.

162. The observation that breeders and farmers sometimes differ in their evaluation of crop varieties has recently led to the development of more participatory approaches to plant breeding, which are expected to develop varieties more suited to resource-poor farmers' needs.<sup>203</sup> Most of such farmers are women.<sup>204</sup> Participatory plant breeding can involve a broad range of options, ranging from plant breeder-controlled decentralised breeding to various degrees of farmer involvement in the breeding or improvement process. Participatory approaches draw upon the comparative advantages of both "informal" crop improvement by farmers and "formal" plant breeding by professionals.<sup>205</sup> Considerable experience in participatory development processes has been gained in many fields including rural development, community health systems and even in industrial product development involving consumers.<sup>206</sup> Less work has been done in the field of participatory breeding.<sup>207</sup>

#### *Methods for valuing PGRFA*

163. A number of methods have been developed by economists for assessing the value of public goods. This work has in turn been applied to the valuation of biological diversity.<sup>208</sup> Many attempts have been made to estimate the value of various ecosystem functions<sup>209</sup> (or "services"), rather than the value of genetic resources for food and agriculture *per se* and,

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<sup>201</sup> Robertson DS (1989) Understanding the relationship between qualitative and quantitative genetics. In Development and Application of Molecular Markers to Problems in Plant Genetics. Helentjaris T and Burr B (eds.) Cold Spring Harbor: Cold Spring Harbor Press.

<sup>202</sup> Hallauer, A. (1992) Recurrent selection in maize. *Plant Breeding Reviews* 9: 115-179.

<sup>203</sup> This section is based upon the Wageningen Workshop on Participatory Breeding (1995), organized jointly by IDRC, FAO, IPGRI and the Dutch Genebank (CGN/CPRO- DLO) which brought together a group of twenty four technical and social scientists actively involved in farmer participatory breeding for less favourable environments from various CGIAR Institutes, some national institutions and donor organizations.

<sup>204</sup> Quisumbing AR, Brown LR, Feldstein HS, Haddad L and Pena C (1995) *Women: The Key to Food Security*, IFPRI: Washington DC.

<sup>205</sup> Berg T, Bjornstad A, Fowler C and Skroppa T (1991) *Technology Options and the Gene Struggle*, Aas: NORAGRIC / Agricultural University of Norway.

<sup>206</sup> Nelson N and Wright S (1995) *Power and Participatory Development : Theory and Practice*, IT Publications : London.

<sup>207</sup> Chambers R Pacey A and Thrupp LA (1993) *Farmer First: Farmer innovation in agricultural research*, IT Publications: London.

<sup>208</sup> Perrings C, Barbier EB, Brown G, Dalmazzone S, Folke C, Gadgil M, Hanley N, Holling CS, Lesser WH, Maler KG, Mason P, panayotou T, Turner RK, and Wells M (1995). *The Economic Value of Biodiversity* press: Cambridge.

<sup>209</sup> Perrings C, Barbier EB, Brown G, Dalmazzone S, Folke C, Gadgil M, Hanley N, Holling CS, Lesser WH, Maler KG, Mason P, panayotou T, Turner RK, and Wells M (1995). *The Economic Value of Biodiversity* press: Cambridge.

consequently, they have little application to the complete valuation of such genetic resources.<sup>210</sup> Most methods value biodiversity as non-marketed goods and services, by estimating people's "willingness to pay", as if they were for sale. There are several approaches of this type, which include:

- *Direct methods* using simulated markets to get users to state their "willingness to pay". Such methods, have not yet been applied to PGRFA.
- *Indirect methods* which use surrogate markets.
- *Production functions* (a type of indirect method) use information about the costs of making a marketed good, and its price, in order to infer the value of non-marketed inputs. Yield gains in agriculture result from genetic and other inputs (including agrochemicals and capital machinery) for which costs are often known.<sup>211</sup> The contribution of genetic resources (in the form of improved varieties) to productivity gains can be estimated, using production-functions.

164. The range of non-financial ways that plant genetic resources matter to local people should be recognised in valuation studies or assessments. Economic valuations based only on direct-use values can often be misleading. Unless a differentiated analysis is carried out, it is difficult to identify the value of plant genetic resources, the perception of which may vary according to season, or other factors. Formal economic methods of valuation often do not take into account "local people's" perspectives, priorities, value concepts, etc., in relation to plant genetic resources. Social and economic valuation methodologies based on local knowledge, uses, and values of wild resources, and involving local men and women in the valuation process, are being developed.<sup>212</sup>

165. A range of legal instruments and other mechanisms are relevant as possible mechanisms which have been dealt with in more detail in previous FAO Commission on Plant Genetic Resources' documents for the sharing of benefits derived from the use of plant genetic resources.<sup>213</sup> In summary, these fall into four categories:

- Intellectual Property Rights (IPR), such as patents<sup>214</sup> and plant breeders rights;<sup>215</sup>
- non-IPR rights over intangible property, such as trade secrets, cultural property rights,<sup>216</sup> remuneration rights, appellations of origin and protection of expression of folklore;<sup>217</sup>
- contractual agreements<sup>218</sup> (including material transfer agreements);<sup>219</sup>

<sup>210</sup> Revision of the International Undertaking. Analysis of some Technical, Economic and Legal Aspects for Consideration in Stage II. CPGR-Ex 1/94/5 supp.

<sup>211</sup> National Research Council (1993) *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*, National Academy Press: Washington DC, Chapter 13.

<sup>212</sup> Hinchcliffe F and Melnyk M (1995) *The Hidden Harvest: The Value of Wild Resources in Agricultural Systems*. IIED: London.

<sup>213</sup> A more complete treatment can be found in CPGR-Ex 1/94/5 supp and Correa (1994), *Sovereign and Property Rights over Plant Genetic Resources*, Commission on Plant Genetic Resources, Background Study Paper No. 2.

<sup>214</sup> Bent et al (1991), *Intellectual Property Rights in Biotechnology Worldwide*. Stockton Press, New York.

<sup>215</sup> Heitz A (1995) An introduction to the protection of new plant varieties and UPOV. Paper presented at the WANA Seed network Council Meeting, March 20-23, 1995, Antalya, Turkey.

<sup>216</sup> Convention on the Means of Prohibiting the Illicit Import, Export and Transfer of Ownership of Cultural Property, administered by UNESCO.

<sup>217</sup> UNESCO/WIPO Model Provisions for the Protection of Expression of Folklore against Illicit Exploitation and other Prejudicial Actions.

<sup>218</sup> For instance, *Biological prospecting contracts* provide a framework for determining rights and obligations, and, in particular, attributing property rights, and regulating the sharing of benefits, in the case of the discovery of plants

- international agreements<sup>220</sup> on access to, use of and remuneration for PGRFA such as the FAO International Undertaking on Plant Genetic Resources.<sup>221</sup>

166. Each of these, alone or in concert, might contribute to bilateral and/or multilateral approaches to the fair and equitable sharing of benefits with countries, communities and farmers. The potential of each option needs to be further explored.

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with new commercial applications. Benefits to donors of germplasm generally take the form of payments, beforehand, for the right to explore, or royalty payments deriving from the use of material discovered, for a given period, or both. Contractors get, in exchange, the right to patent, or otherwise exclusively exploit, materials discovered. This type of contract has so far been applied to wild plants and resultant biochemicals for medicinal or industrial purposes, but not yet to the collection of plant genetic resources for food and agriculture. The Inbio-Merck agreement, in Costa Rica, is the best known example of a bio-prospecting contract. A further example is the agreement among Bristol Myers Squibb, Conservation International, and the Tiriò People of Suriname.

<sup>219</sup> Barton J., and Siebeck W (1994) "Material transfer agreements in genetic resource exchange. The case of the International Agricultural Research Centres"; Issues in Genetic Resources, No.1; IPGRI, Rome, May 1994.

<sup>220</sup> The World Heritage Fund of the UNESCO-sponsored World Heritage Convention provides a useful model of such agreements. Funds are provided, on a continuous basis, in return for the continued conservation of sites on the World Heritage List. Funds are raised as mandatory assessments on developed countries, and, in effect, are a form of international income tax on countries, assessed according to their ability to pay.

<sup>221</sup> FAO Conference Resolutions 8/83, 4/89, 5/89 and 3/91.

Method	Variation detected	Sample throughput	loci analysed per assay	reproducibility between assays	type of character analysed	inheritance of character analysed	technology level required
Morphology <sup>1</sup>	low	high	low no.	medium	phenotypic trait	qualitative / quantitative	low
Pedigree analysis <sup>2</sup>	medium	n.a.	n.a.	good	degree of coancestry	n.a.	low
Isozymes <sup>3</sup>	medium	medium	low no.	medium	proteins	co-dominant	medium
RFLP (low copy)	medium	low	low no. (specific)	good	DNA	co-dominant	high
RFLP (high copy)	high	low	high no. (specific)	good	DNA	dominant	high
RAPD <sup>4</sup>	high to medium	high	high no. (random)	poor	DNA	dominant	medium
DNA sequencing <sup>5</sup>	high	low	low no. (specific)	good	DNA	co-dom. / dominant	high
Seq tag	high	high	medium no (specific)	good	DNA	co-dominant	high
SSRs <sup>6</sup>	high	high	high no. (random)	medium	DNA	dominant	high
AFLPs <sup>7</sup>	medium to high	high	high no. (random)	medium	DNA	dominant	high

## References for Table 9.1

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- 3: Brown AHD and Clegg MT (1983) Isozyme assessment of plant genetic resources. Current Topics in Biological and Medical Research 11:285-295.
- 4: Tingey SV and Del Tufo JP (1993) Genetic analysis with RAPD markers. Plant Physiology 101:349-352.
- 5: Sasaki T, Song J, Koga-Ban Y, Matsui E, Fang F, Higo H, Nagasaki H, Hori M, Miya M, Murayama-Kayano, E, Takiguchi T, Takasuga A, Niki T, Ishimaru K, Ikeda H, Yamamoto Y, Mukai Y, Ohta I, Miyadera N, Havukkala I and Minobe Y (1994) Toward cataloguing all rice genes: Large scale sequencing of randomly chosen rice cDNAs from a callus cDNA library. Plant Journal 6:615-624.
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- 7: Keygene NY (1991) Selective restriction fragment amplification: a general method for DNA fingerprinting. European Patent # EP534858 (24/9/91).

**Table 9.2 Some species with recalcitrant seeds**

Species	Crop name	Species	Crop name
<i>Araucaria</i> spp.	Araucaria	<i>Mangifera</i> spp.	Mango
<i>Castanea</i> spp.	Chestnut	<i>Manilkara achras</i>	Zapote
<i>Chrysophyllum cainito</i>	Caimito	<i>Myristica fragrans</i>	Nutmeg
<i>Cinnamomum ceylanicum</i>	Cinnamon	<i>Nephelium lappaceum</i>	Rambutan
<i>Cocos nucifera</i>	Coconut	<i>Persea</i> spp.	Avocado
<i>Diospyros</i> spp.	Ebony	<i>Quercus</i> spp.	Oak
<i>Durio</i> spp.	Durian	<i>Spondias</i> spp.	Jocote
<i>Erythoxylum coca</i>	Coca	<i>Swietenia mahogoni</i>	Mahogany
<i>Garcinia</i> spp.	Mangosteen	<i>Syzygium aromaticum</i>	Cloves
<i>Hevea brasiliensis</i>	Rubber tree	<i>Theobroma cacao</i>	Cocoa
		<i>Thea sinensis</i>	Tea

Source: Cromarty AS, Ellis RH and Roberts EH (1985) *The design of seed storage facilities for genetic conservation*, IBPGR Handbooks for Genebanks No 1, Roma, 96 pp.

**Table 9.3: Technologies for *ex situ* conservation of different types of PGRFA**

Storage technology	Tissue type	Appropriate Function
Low temperature (-18°C) and 3-7% moisture content <sup>1</sup>	Orthodox seeds	long term conservation (base collection) provision of accessions for use (active collections)
Desiccated seeds at cool temperature	Orthodox seeds	provision of accessions for use (active & working collections); medium term conservation
Ultra-dry seeds at room temperature	Orthodox seeds	medium to long term conservation
Storage of dried seeds at room temperature.	Some long lived orthodox seeded species	provision of accessions for use (active & working collections)
Cultivation of entire plants in field genebank	Vegetatively propagated species, recalcitrant seeded species, long life-cycle species and species with limited seed production	short or medium term conservation; provision of accessions for use (active collections)
Slow growth in <i>in vitro</i> culture	Vegetatively propagated species and some recalcitrant seeded species	medium term conservation; provision of accessions for use (active collections)
Cryopreservation at -196°C in liquid nitrogen	Seeds, pollen, tissue, cells, embryos of species capable of <i>in vitro</i> regeneration after drying and freezing.	long term conservation

<sup>1</sup> The precise storage regime can vary depending on the species, environment and cost considerations but should ensure the maintenance of seed viability above 65% for 10-20 years.

Figure 9.1: Relative cost and technical complexity of some crop improvement technologies

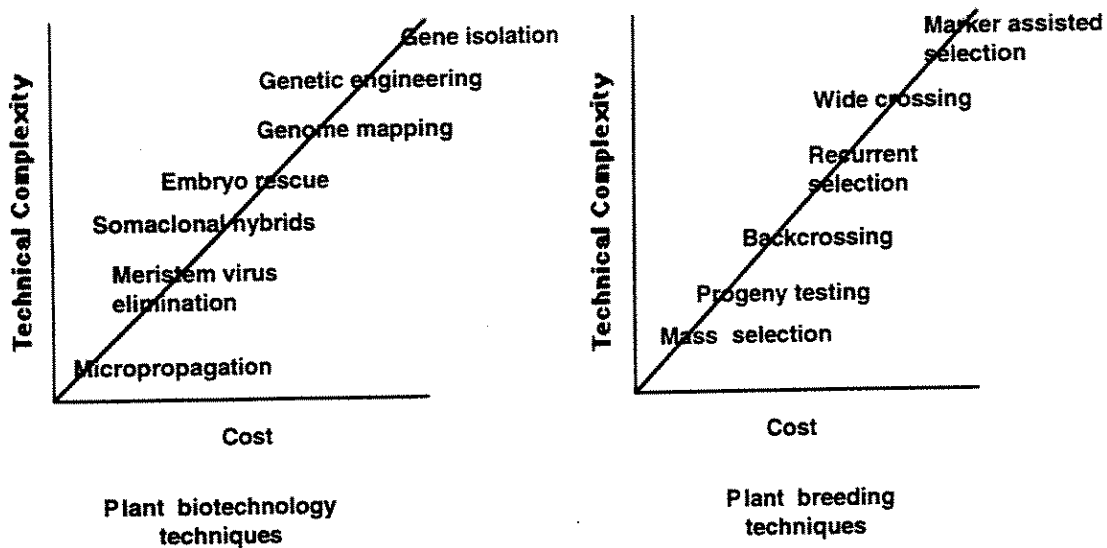


Table 9.4: List of some plant species for which genome mapping projects are underway internationally

Alfalfa	Celery	Lentil	Pepper	Spruce
Almond	Cereal	Lettuce	Pine	Squash
Apple	Chrysanthemum	Lilium	Plum	Sugarcane
Arabidopsis	Citrus	Melon	Poplar	Sunflower
Asparagus	Clover	Oat	Potato	Tobacco
Barley	Cocoa	Onion	Rice	Tomato
Bean	Corn	Papaya	Rose	Turf Grass
Berry	Cotton	Pea	Rye	Wheat
Brassicas	Cucumber	Peach	Snapdragon	
Cabbage	Cuphea	Peanut	Sorghum	
Carrot	Grasses	Pear	Soybean	

Source: USDA, 1995.

The information provided is derived from Country Reports and the World Information and Early Warning System (WIEWS). It will be finalized after verification and/or correction by countries.

## Legend

1. Participation in the Preparatory Process for the International Technical Conference: ○ (focal point), ● (country report), ● (sub-regional meeting), ● (country report + sub-regional meeting).
2. Countries and territories are listed according to the sub-regions used during the preparatory process for the International Technical Conference.
3. FAO Global System (CGRFA = Commission on Genetic Resources for Food and Agriculture; IU = International Undertaking): ○ (not available), ● (Member of CGRFA), ● (signed IU), ● (CGRFA + IU).
4. Convention of Biodiversity: ○ (signed), ● (ratified).
5. Quarantine Policy : ○ (national regulations), ● (member International Plant Protection Convention ).
6. Plant Breeders' Rights (UPOV = International Union for the Protection of new Varieties of Plants): ○ (other than UPOV), ● (UPOV 1978 pre 1991), ● (UPOV 1978 post 1991), ● (UPOV 1991).
7. Seed Quality Control: ● (Seed Quality Control), ● (Seed Certification).
8. National Programmes: ○ (under development), ● (without a formal national programme, but with a functioning national committee or other mechanism to coordinate national PGRFA activities.), ● (with a formal national programme comprising a number of institutions, on a sectorial basis, and a mechanism to coordinate national PGRFA activities.), ● (with a formal national programme comprising a central institute which coordinates national PGRFA activities as well as carrying out some activities.).
9. Conservation *ex situ* (LT = Long Term; MT = Medium Term; ST = Short Term): ○ (no gene bank), ● (ST/MT Storage), ● (LT storage or MT/LT), ● (LT managed).
10. Crop Improvement programme status: ○ (no programme), ● (basic), ● (developed), ● (advanced).
11. Sub-Regional Networks: ECP (European Co-operative Programme for Crop Genetic Resources Network), WANA (The West Asia and North PGR Network), SPG (Southern African Development Community PGR Centre), SAS (PGR Network for South Asia), EAS (PGR Network for East Asia), REC (Regional Cooperation in Southeast Asia on PGR), RED (Andean Network on PGR), PRO (PGR Sub-regional network for the countries of the southern cone), TRO (Amazonia Network on PGR), REM (Mesoamerican Network on PGR), CCM (Caribbean Committee on Management of PGR).
12. Information concerning the number of accessions held by countries is available from two sources: the Country Reports, and the WIEWS database. Where information is available from both sources, the larger number is provided. Differences between the two sources are usually due to differences in the number of institutions included in a country's listing.



Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>		
	<b>Western Europe</b>										
●	Andorra	●	●	●	○	○	○	●	●	ECP	7,891
●	Austria	●	○	●	●	○	○	●	●	ECP	9,750
●	Belgium	●	○	●	●	○	○	●	●	ECP	3,660
●	Denmark	●	●	●	●	○	○	●	●	ECP	2,323
●	Finland	●	●	●	○	○	○	●	●	ECP	249,389
●	France	●	●	●	●	○	○	●	●	ECP	200,000
●	Germany	●	●	●	●	○	○	●	●	ECP	17,556
●	Greece	●	●	●	●	○	○	●	●	ECP	
●	Iceland	●	●	○	○	○	○	●	●	ECP	
●	Ireland	●	○	●	●	○	○	○	●	ECP	2,758
●	Italy	●	●	●	●	○	○	●	●	ECP	80,000
	Lichtenstein	○	○	●	●	○	○	○	○		
	Luxembourg	○	○	●	●	○	○	○	○		
	Monaco	○	○	●	●	○	○	○	○		
●	Netherlands	●	●	●	●	○	○	●	●	ECP	67,374
●	Norway	●	●	●	○	○	○	●	●	ECP	1,133
●	Portugal	●	●	●	○	○	○	●	●	ECP	29,361
	San Marino	○	○	●	●	○	○	○	○		
●	Spain	●	●	●	●	○	○	●	●	ECP	78,174
●	Sweden	●	●	●	●	○	○	●	●	ECP	89,206
●	Switzerland	●	●	○	●	○	○	●	●	ECP	17,000
●	United Kingdom	●	●	●	●	○	○	●	●	ECP	114,495
	<b>Eastern Europe</b>										
○	Albania	○	●	○	○	○	○	○	○		20,000
○	Armenia	○	●	○	○	○	○	○	○		2,000
●	Belarus	○	●	○	○	○	○	○	○		4,000
	Bosnia and Herzegovina	○	○	○	○	○	○	○	○		31
○	Bulgaria	●	○	●	○	○	○	○	○	ECP	55,420
●	Croatia	○	○	○	○	○	○	○	○		15,336
●	Czech Republic	●	●	●	○	○	○	○	○	ECP	51,571
●	Estonia	○	●	○	○	○	○	○	○		3,000
	Georgia	○	●	○	○	○	○	○	○		
●	Hungary	●	●	●	○	○	○	○	○	ECP	75,170
●	Latvia	○	○	○	○	○	○	○	○		9,730
●	Lithuania	○	○	○	○	○	○	○	○	ECP	12,821
	The Former Yugoslav Republic of Macedonia	○	○	○	○	○	○	○	○		
●	Moldova	○	○	○	○	○	○	○	○		6,000
●	Poland	●	○	○	○	○	○	○	○	ECP	91,802
●	Romania	●	●	●	○	○	○	○	○	ECP	93,000
●	Russia	○	●	●	○	○	○	○	○	ECP	333,000
●	Slovakia	○	●	○	○	○	○	○	○	ECP	14,547
○	Slovenia	○	○	○	○	○	○	○	○		2,676
●	Ukraine	○	○	○	○	○	○	○	○		136,400
○	Yugoslavia	●	○	●	○	○	○	○	○	ECP	38,000

Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>	
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>			
	<b>South/East Mediterranean</b>											
●	Algeria	●	●	●						WANA	985	
●	Cyprus	●	○	○		○		○	○	ECP, WANA	12,313	
●	Egypt	●	●	●				○	○	WANA	8,914	
●	Israel	●	●	●	●			○	○	ECP	56,123	
●	Jordan	○	●	●				○	○	WANA	3,588	
●	Lebanon	●	●	●					○	WANA		
○	Libyan	●		●					○	WANA	2,313	
	Malta	○		●					○			
●	Morocco	●	●	●				○	○	WANA	20,470	
	Palestine	○										
●	Syria	●		○				○	○	WANA	8,750	
●	Tunisia	●	●	●				○	○	WANA	1,768	
	<b>West Asia</b>											
	Afghanistan	○	○								2,965	
	Bahrain	○	○	●								
●	Iran, Islamic Republic of	●	○	●				●	●	○	WANA	40,000
●	Iraq	●		●				●	○	○	WANA	6,400
	Kuwait	○	○									
○	Oman	○	●	●					○	○	WANA	238
●	Pakistan	○	●	●				●	●	○	WANA	19,208
○	Qatar	○	○					○	○	○		
○	Saudi Arabia, Kingdom of	○						○	○	○		
●	Turkey	●	○	●				○	●	●	ECP, WANA	26,867
	United Arab Emirates	○	○									
●	Yemen	●	○	●				○	○	○	WANA	4,229
	<b>Central Asia</b>											
●	Azerbaijan	○	○	○				○	○	○	25,000	
●	Kazakhstan	○	●	○				○	○	○	33,000	
	Kyrgyz, Republic	○										
	Tajikistan	○										
●	Turkmenistan	○		○					○	○	4,832	
●	Uzbekistan	○	●	○				○	○	○	50,000	

Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>		
	<b>West Africa</b>										
●	Benin	●	●	○		○		●	●		2,453
●	Burkina Faso	●	●	●		○		●	●		850
○	Cape Verde	●	●	●				●	●		
	Chad	●	●			○					69
○	Cote d'Ivoire	○	●	○		○		●	●		22,498
●	Gambia	○	●			○		●	●		
●	Ghana	●	●	●		○	●	●	●		2,987
○	Guinea-Bissau	●	●								
	Guinea	○	●	●				●	●		899
	Liberia	●	○	●		○					1,707
○	Mali	●	●	●		○		○			248
○	Mauritania	●	○			○					
●	Niger	●	●	●		○		●	●		
●	Nigeria	○	●	●		○	●	●	●		12,324
●	Senegal	●	●	●		○		●	●		12,000
●	Sierra Leone	●	●	●		○		○	○		1,848
●	Togo	●	●	●		○		○	○		4,000
	<b>Central Africa</b>										
●	Cameroon	●	●	○		○		○	○		2,329
●	Central African Republic	●	●					○	○		
●	Congo	●	○	○		○		○	○		1,755
●	Equatorial Guinea	●	●	●				○	○		
●	Gabon	●	○	○				○	○		91
	Sao Tome and Principe	○	○								
●	Zaire	○	●	○		○		○	○		18,830
	<b>Southern Africa</b>										
●	Angola	●	○					○	○	SPG	599
●	Botswana	○	●	○		○		●	●	SPG	3,390
●	Lesotho	○	●			○		○	○	SPG	
●	Malawi	●	●	●		○		●	●	SPG	11,421
●	Mozambique	○	●	○		○		○	○	SPG	1,872
●	Namibia	○	○			○		○	○	SPG	1,600
●	South Africa	●	●	●	○	○		○	○	SPG	48,918
●	Swaziland	○	○	○		○		○	○	SPG	
●	Tanzania	●	○	○		○		○	○	SPG	2,510
●	Zambia	●	●	●		○		○	○	SPG	5,901
●	Zimbabwe	●	●	○	○	○		○	○	SPG	45,698

Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>		
	<b>East Africa</b>										
●	Burundi	○	○			○					
	Djibouti	○	●								
●	Eritrea	○	○				○	○	○		1,087
●	Ethiopia	●	●	●	○	○	●	●	○		54,000
●	Kenya	●	●	●	○	○	○	●	●		50,037
○	Rwanda	●	○			○	○	○	○		6,168
	Somalia	○									94
●	Sudan	●	●	●			○	○	○		5,178
●	Uganda	○	●	○		○	○	○	○		11,483
	<b>Indian Ocean Islands</b>										
	Comoros	○	●								
●	Madagascar	●	○	○		○		○	○		15,000
●	Mauritius	●	●	●		○		○	○	SPG	3,310
●	Seychelles	○	●	○				○	○		369
	<b>South Asia</b>										
●	Bangladesh	●	●	●		○		○	○	SAS	45,309
	Bhutan	○	●	●						SAS	40
●	India	●	●	●		○	●	●	●	SAS	342,108
●	Maldives	○	●					○	○	SAS	
●	Nepal	●	●	○				○	○	SAS	8,383
●	Sri Lanka	●	●	●		○		○	○	SAS	11,781
	<b>South East Asia</b>										
	Brunei	○				○				FEC	
●	Cambodia	○	●	●						FEC	2,155
●	Indonesia	○	●	●		○	○	○	○	FEC	26,828
	Laos	○		●		○				FEC	
●	Malaysia	○	●	●		○	○	○	○	FEC	38,255
●	Myanmar	○	●	○				○	○	FEC	8,000
●	Philippines	●	●	●		○	○	●	●	FEC	59,399
	Singapore	○								FEC	
●	Thailand	○	○	●		○	○	○	○	FEC	32,404
●	Viet Nam	○	●	○		○	○	○	○	FEC	21,493
	<b>East Asia</b>										
●	China	○	●	○		○	●	●	●	EAS	350,000
●	Japan	○	●	●	○	○	○	●	●	EAS	202,581
●	Korea, Dem People's Republic of	●	●	○		○	●	○	○	EAS	100,000
●	Korea, Republic of	●	●	●	○	○	●	●	●	EAS	120,000
●	Mongolia	○	●	○			○	○	○	EAS	24,000

Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>		
	<b>Pacific Region</b>										
<input type="radio"/>	Australia	●	●	●	●	●					94,768
<input checked="" type="radio"/>	Cook Islands	○	●	○				●	●		91
<input type="radio"/>	Fiji	●	●								943
	Kiribati	○	●								14
	Marshall Islands	○	●								
	Micronesia	○	●								
	Nauru	○	●								
<input type="radio"/>	New Zealand	●	●	●	●	●					28,914
<input checked="" type="radio"/>	Niue	○		○				○	○		94
	Palau	○									
●	Papua New Guinea	○	●	●				●	●		5,656
●	Samoa	●	●					●	●		138
●	Solomon Islands	●	●	●				●	●		1,130
●	Tonga	●		○				●	○		8
	Tuvalu	○	○								40
	Vanuatu	●	●								664
	<b>South America</b>										
●	Argentina	●	●	●	●	●		●	●	RED, PRO	30,000
●	Bolivia	●	●	●	○	●		●	●	TRO, RED, PRO	11,069
●	Brazil	●	●	●	●	●	●	●	●	TRO, PRO	194,000
●	Chile	●	●	●	●	●		●	●	RED, PRO	36,000
●	Colombia	●	●	●	○	●		●	●	TRO, RED	85,000
●	Ecuador	●	●	●	○	●		●	●	TRO, RED	35,780
●	Paraguay	●	●	●	○	●		●	●	PRO	1,571
●	Peru	●	●	●	○	●		●	●	TRO, RED	44,833
●	Uruguay	●	●	●	●	●	●	●	●	PRO	1,256
●	Venezuela	●	●	●	○	●		●	●	TRO, RED	15,356
	<b>Central America &amp; Mexico</b>										
●	Costa Rica	●	●	●		●	●	●	●	FEM	5,057
●	El Salvador	●	●	●		●	●	●	●	FEM	1,547
●	Guatemala	●	●	●		●	●	●	●	FEM	2,796
●	Honduras	●	●	○		●	●	●	●	FEM	4,457
●	Mexico	●	●	●		●	●	●	●	FEM	103,305
●	Nicaragua	●	○	●		●	●	●	●	FEM	2,976
●	Panama	●	●	●		●	●	●	●	FEM	1,538

Preparatory Process <sup>1</sup>	Country <sup>2</sup>	FAO Global System <sup>3</sup>	Conv. of Biodiversity <sup>4</sup>	Legislation			National Capacity			(sub)regional network <sup>11</sup>	Genebank Accessions <sup>12</sup>
				Quarantine <sup>5</sup>	Plant Breeders' Rights <sup>6</sup>	Seed Quality Control <sup>7</sup>	National programmes <sup>8</sup>	Conservation ex-situ <sup>9</sup>	Crop Improvement <sup>10</sup>		
	<b>Caribbean</b>										
●	Antigua and Barbuda	○	●	○		○		○	CCM		
●	Bahamas	●	●	○				○	CCM		
●	Barbados	●	●	●				○	CCM		2,868
	Belize	●	●	●				○	CCM		80
●	Cuba	●	●	●		○	○	●	CCM		18,668
●	Dominica	●	●	○				○	CCM		
●	Dominican Republic	●	○	●		○		○	CCM		2,024
●	Grenada	●	●	●				○	CCM		
○	Guyana	○	●	●		○		○	TRO		
●	Haiti	●	○	●		○		○	CCM		
●	Jamaica	●	●	●		○		○	CCM		795
	Puerto Rico	○									4,000
●	Saint Kitts and Nevis	○	●	●				○	CCM		
●	Saint Lucia	○	●	○				○	CCM		58
	Saint Vincent and the Grenadines	○		○				○	CCM		
●	Suriname	○	○	●		○		○	TRO		
●	Trinidad and Tobago	●	○	●		○		○	CCM		2,315
	<b>North America</b>										
●	Canada	○	●	●	●	○	○	●			212,061
●	United States of America	○		●	●	○	●	●			550,000

Crop		Total Accessions worldwide	Storage facilities (%)				Type of accession (%)			
Grouping	Genus		LT	MT	ST	others*	WS	LR/OC	AC/BL	others**
<b>Cereal</b>										
Wheat	<i>Triticum</i>	774 500	11	49	4	36	2	18	20	61
Barley	<i>Hordeum</i>	485 000	8	44	2	46	1	9	10	84
Rice	<i>Oryza</i>	408 500	14	21	10	54	1	22	7	71
Maize	<i>Zea</i>	277 000	10	39	11	34	0	16	10	67
Oat	<i>Avena</i>	222 500	19	24	7	36	4	1	5	76
Sorghum	<i>Sorghum</i>	168 500	25	35	17	27	0	18	21	60
Millet	Millet	90 500	22	64	10	10	2	33	5	63
Wheat	<i>Triticale</i>	40 000	0	56	0	15	0	0	54	46
Rye	<i>Secale</i>	27 000	12	36	4	47	0	1	8	90
Wheat	<i>Aegilops</i>	20 500	5	48	0	47	53	0	0	47
Chenopodium	<i>Chenopodium</i>	2 500	0	0	95	5	0	0	0	100
<b>Food legume</b>										
Bean	<i>Phaseolus</i>	268 500	6	21	5	68	1	6	17	91
Soybean	<i>Glycine</i>	174 500	24	25	8	43	1	2	7	92
Cowpea	<i>Vigna</i>	85 500	31	34	1	33	1	3	0	97
Groundnut	<i>Arachis</i>	81 000	16	20	14	53	1	15	11	72
Pea	<i>Pisum</i>	75 500	10	23	2	66	0	9	7	84
Chickpea	<i>Cicer</i>	67 000	5	66	2	32	1	39	7	52
Faba bean	<i>Vicia</i>	29 500	6	44	3	47	0	31	10	59
Lupin	<i>Lupinus</i>	28 500	4	34	5	58	16	12	10	63
Lentil	<i>Lens</i>	25 000	1	55	0	44	3	38	6	53
Pigeonpea	<i>Cajanus</i>	25 000	10	56	0	44	2	50	7	38
Winged bean	<i>Psophocarpus</i>	5 000	0	0	21	79	0	21	0	79
Bambara groundnut	<i>Voandzeia</i>	3 500	59	0	0	41	0	100	0	0
<b>Root</b>										
Sweet potato	<i>Ipomoea</i>	32 000	0	0	0	100	0	0	0	100
Potato	<i>Solanum</i>	31 000	0	20	11	69	5	12	19	63
Cassava	<i>Manihot</i>	28 000	0	8	0	92	1	0	24	74
Yam	<i>Dioscorea</i>	11 500	0	64	0	36	0	60	4	36
<b>Vegetable</b>										
Brassica	<i>Brassica</i>	109 000	10	12	13	65	0	15	11	74
Tomato	<i>Lycopersicon</i>	78 000	19	18	9	12	0	1	24	34
Capsicum	<i>Capsicum</i>	53 500	4	31	17	48	0	6	15	79
Onion/garlic	<i>Allium</i>	25 500	8	25	10	57	0	15	6	79
Cucurbita	<i>Cucurbits</i>	17 500	7	43	0	50	0	18	0	82
Okra	<i>Abelmoschus</i>	6 500	0	48	0	52	0	26	0	74
Carrot	<i>Daucus</i>	6 000	24	29	0	47	8	0	16	76
Radish	<i>Raphanus</i>	5 500	0	22	0	78	0	22	0	78
<b>Fruit</b>										
Apple	<i>Malus</i>	97 500	0	1	0	99	0	5	49	46
Prunus	<i>Prunus</i>	64 500	0	0	0	100	2	2	27	68
Grape	<i>Vitis</i>	47 000	5	0	0	95	0	7	20	72
Melon	<i>Cucumis</i>	13 500	18	68	0	14	0	4	8	87
Strawberry	<i>Fragaria</i>	13 500	0	0	0	100	12	0	17	71
Ribes	<i>Ribes</i>	13 000	0	0	0	100	1	1	3	96
Rosa	<i>Rosa</i>	10 000	0	2	0	98	0	8	7	84
Citrus	<i>Citrus</i>	6 000	0	0	0	100	0	0	0	100
Cashew nut	<i>Anacardium</i>	5 500	0	0	0	100	23	0	0	77
Melon	<i>Citrullus</i>	4 500	0	89	0	11	0	0	0	100
Beach Palm	<i>Bactris</i>	3 000	0	0	0	100	0	0	0	100
Hazel nut	<i>Corylus</i>	2 500	0	0	0	100	0	0	0	100
Sorbus	<i>Sorbus</i>	2 000	0	0	0	100	3	1	31	66
Pear	<i>Pyrus</i>	1 000	0	0	0	100	0	0	100	0

Crop		Total Accessions worldwide	Storage facilities (%)				Type of accession (%)			
Grouping	Genus		LT	MT	ST	others*	WS	LR/OC	AC/BL	others**
<b>Oil</b>										
Sunflower	<i>Helianthus</i>	29 500	0	1	24	75	3	4	54	39
Palm	<i>Elaeis</i>	21 500	0	0	0	100	0	0	0	100
Sesame	<i>Sesamum</i>	18 000	19	17	7	56	0	0	0	100
Safflower	<i>Carthamus</i>	8 500	0	37	0	63	0	0	0	100
Castor oil	<i>Ricinus</i>	3 000	0	0	0	100	0	0	0	100
Other oils	Oil	16 000	0	0	0	100	0	0	0	100
<b>Sugar</b>										
Beet	<i>Beta</i>	24 000	1	48	0	51	23	6	23	49
Sugarcane	<i>Saccharum</i>	19 000	0	0	0	100	0	0	10	90
<b>Forage (legume)</b>										
Clover	<i>Trifolium</i>	64 000	2	43	0	55	14	0	0	86
Medicago	<i>Medicago</i>	33 000	7	29	0	64	31	0	0	69
Vicia	<i>Vicia</i>	26 500	7	31	0	50	27	5	0	56
Grass pea	<i>Lathyrus</i>	13 500	0	87	0	0	62	1	0	25
Trefoil	<i>Lotus</i>	3 500	0	50	0	50	0	0	0	100
Legumes	others	31 000	0	32	0	68	92	0	1	8
<b>Forage (grass)</b>										
Grass	<i>Dactylis</i>	27 000	0	51	0	49	3	41	1	55
Fescue	<i>Festuca</i>	24 000	0	29	0	71	5	18	1	76
Grass	<i>Lolium</i>	24 000	0	37	0	63	0	11	2	87
Grass	<i>Panicum</i>	21 000	1	6	5	89	0	3	0	97
Timothy grass	<i>Phleum</i>	9 000	0	55	0	45	0	53	2	45
Grass	<i>Poa</i>	8 000	0	29	0	71	0	28	1	71
Grass	<i>Bromus</i>	4 500	0	52	0	48	0	0	0	100
Grass	<i>Elymus</i>	2 500	0	0	0	100	0	0	0	100
Grass	<i>Cenchrus</i>	2 000	52	0	0	48	52	0	0	48
Grass	<i>Andropogon</i>	1 500	0	0	0	100	0	0	0	100
Grass	others	18 000	0	33	0	67	63	0	1	36
<b>Fiber</b>										
Cotton	<i>Gossypium</i>	49 000	6	0	0	93	1	7	9	82
Flax	<i>Linum</i>	25 000	0	34	18	49	0	2	6	92
Jute	<i>Corchorus</i>	2 500	62	0	0	38	0	50	9	41
<b>Beverage</b>										
Coffee	<i>Coffea</i>	21 000	0	0	0	100	29	0	22	49
Cocoa	<i>Theobroma</i>	9 500	0	0	0	100	2	0	22	98
<b>Medicinal</b>										
Opium	<i>Papaver</i>	7 000	0	47	0	53	0	0	0	100
<b>Miscellaneous</b>										
Arabidopsis	<i>Arabidopsis</i>	27 000	30	0	0	70	3	0	27	70

Main source: WIEWS database. (Some modifications made according to CGIAR-SGRP Genebank Reviews and national genebank reports).

\* mixed (LT+MT+LT) + field storage + cryopreserved + in vitro + unknown

\*\* mixed + unknown

LT: Long term, MT: Medium term, ST: Short term

WS: wild species, LR/OC: landraces &/or old cultivars, AC/BL: advanced cultivars &/or breeding lines