# The State of the World's Plant Genetic Resources for Food and Agriculture

Food and Agriculture Organization of the United Nations

# THE STATE OF THE WORLD'S PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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# acronyms and abbreviations[1]

| | |
|---|---|
| **ACIAR** | Australian Council for International Agricultural Research |
| **ACSAD** | Arab Centre for the Studies of Arid Zones and Dry Lands |
| **ACTS** | African Centre for Technology Studies |
| **AFLP** | amplified fragment length polymorphism |
| **AFNETA** | Alley Farming Network for Tropical Africa |
| **AFRENA** | Agroforestry Research Network for the Highlands of East and Central Africa |
| **AMCEN** | African Ministerial Conference on Environment |
| **ANZNPGRC** | Australian and New Zealand Network of Plant Genetic Resource Centres |
| **APSA** | Asia Pacific Seed Association |
| **ASARECA** | Association of Agricultural Research in East and Central Africa |
| **ASEAN** | Association of Southeast-Asian Nations |
| **ASEAN-PLANTI** | Asian Plant Quarantine Centre and Training Institute |
| **AS-PTA** | Assesoria e Servicos à Projetos em Agricultura Alternativa (NGO, Brazil) |
| **AVRDC** | Asian Vegetable Research and Development Centre |
| **BGCI** | International Association of Botanic Gardens |
| **BMZ** | German Ministry for Economic Cooperation and Development |
| **BRAHAMS** | Botanical Research and Herbarium Management Systems |
| **CAA** | Community Aid Abroad (Australia) |
| **CAPGRIS** | Canadian Agricultural Plant Genetic Resources Information System |
| **CARDI** | Caribbean Agricultural Research and Development Institute |
| **CARICOM** | Caribbean Community |
| **CATIE** | Tropical Agricultural Research and Training Centre |
| **CBD** | Convention on Biological Diversity |

| | |
|---|---|
| **CBDC** | Community Biodiversity Development and Conservation Programme |
| **CENARGEN** | Centro Nacional de Recursos Geneticos (Brazil) |
| **CET** | Centro de Educación y Tecnología (NGO, Chile) |
| **CGIAR** | Consultative Group on International Agricultural Research |
| **CGN** | Centre for Genetic Resources of the Netherlands |
| **CIAT** | International Centre for Tropical Agriculture (CGIAR) |
| **CICD** | Centro de Investigación y Capacitación para el Desarollo (NGO, Peru) |
| **CIDA** | Canadian International Development Agency |
| **CIFOR** | Centre for International Forestry Research (CGIAR) |
| **CIMMYT** | Centro Internacional de Mejoramiento de Maíz y Trigo International Centre for Maize and Wheat Improvement (CGIAR) |
| **CIP** | International Potato Centre (CGIAR) |
| **CIRAD** | Centre de coopération internationale en recherche agronomique pour le développement (France) |
| **CLADES** | Latin American Consortium on Agro-ecology and Development |
| **CNR** | National Research Council of Italy |
| **COGENT** | Coconut Genetic Resources Network |
| **COMECON** | Council for Mutual Economic Assistance |
| **COMMUTEC** | Community Technology Development Association (NGO, Zimbabwe) |
| **CONSERVE** | Community-based Native Seed Research Centre (NGO, the Philippines) |
| **CoP/CBD** | Conference of the Parties of the Convention on Biological Diversity |
| **CORAF** | Conference of Directors of Agronomic Research in West and Central Africa |
| **CPGR** | FAO Commission on Plant Genetic Resources |
| **CSC** | Commonwealth Science Council |
| **CSEGRIN** | Caribbean Seed and Germplasm Resources Information Network |

| | |
|---|---|
| **CTA** | Technical Centre for Agricultural and Rural Cooperation |
| **DNA** | desoxyribonucleic acid |
| **DUS** | distinct, uniform and stable |
| **EARCORBE** | East African Regional Cooperative for Research on Banana and Enset |
| **EARRNET** | East African Root Crops Research Network |
| **EARSMN** | Eastern Africa Research on Sorghum and Millet Network |
| **ECP/GR** | European Cooperative Programme on Crop Genetic Resources Networks |
| **EEC** | European Economic Community |
| **ESCORENA** | European System of Cooperative Research Networks in Agriculture |
| **EU** | European Union |
| **EUFORGEN** | European Forest Genetic Resources Network |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **GATT** | General Agreement on Tariffs and Trade |
| **GBS** | Global Biodiversity Strategy (IUCN/UNEP/WWF) |
| **GDP** | gross domestic product |
| **GEF** | Global Environment Facility (World Bank/UNEP/UNDP) |
| **GEM** | Germplasm Enhancement Maize Project (United States) |
| **GEPA** | Aktion Dritte Welt Handel (NGO, Germany) |
| **GIS** | Geographic Information System |
| **GRAIN** | Genetic Resources Action International (NGO, Spain) |
| **GRIN** | Germplasm Resources Information Network (United States) |
| **GRUs** | genetic resource units |
| **GTZ** | German Agency for Technical Cooperation |
| **HYV** | high-yielding variety |
| **IABG** | International Association of Botanic Gardens |
| **IACNET** | Inter-american Citrus Network |
| **IADB** | Inter-american Development Bank |
| **IARCs** | International Agricultural Research Centres |

| | |
|---|---|
| **IBPGR** | International Board for Plant Genetic Resources (CGIAR, now IPGRI) |
| **IBS** | Intermediary Biotechnology Service |
| **ICARDA** | International Centre for Agricultural Research in the Dry Areas (CGIAR ) |
| **ICRAF** | International Center for Research in Agroforestry (CGIAR ) |
| **ICRISAT** | International Crops Research Institute for the Semi-Arid Tropics |
| **ICSU** | International Council of Scientific Unions |
| **ICUC** | International Centre for Underutilized Crops |
| **ICWG-GR** | Inter-Centre Working Group on Genetic Resources (CGIAR) |
| **IDRC** | International Development Research Centre |
| **IFAD** | International Fund for Agricultural Development |
| **IFPRI** | International Food Policy Research Institute (CGIAR) |
| **IGADD** | Inter-governmental Authority on Drought and Development |
| **IICA** | Inter-American Institute for Cooperation on Agriculture |
| **IIED** | International Institute for Environment and Development |
| **IITA** | International Institute of Tropical Agriculture (CGIAR) |
| **ILO** | International Labour Organisation |
| **ILRI** | International Livestock Research Institute (CGIAR) |
| **IMC** | Instituto Mayor Campesino (NGO, Colombia) |
| **IMF** | International Monetary Fund |
| **INBAR** | International Network for Bamboo and Rattan |
| **INGER** | International Network for the Genetic Evaluation of Rice |
| **INIBAP** | International Network for the Improvement of Bananas and Plantains |
| **IPGRI** | International Plant Genetic Resources Institute (CGIAR, formerly IBPGR) |

| | |
|---|---|
| **IPK** | Institut für Pflanzengenetik und Kulturpflanzenforschung (Germany) |
| **IPPC** | International Plant Protection Convention |
| **IPR** | intellectual property rights |
| **IRGDB** | International Rice Genealogy Database |
| **IRRI** | International Rice Research Institute (CGIAR) |
| **ISAAA** | International Service for the Acquisition of Agri-biotech Applications |
| **ISNAR** | International Service for National Agricultural Research (CGIAR) |
| **ISSC** | International Species Survival Commission |
| **ITCPGR** | International Technical Conference on Plant Gentic Resources (1996) (FAO) |
| **IUBS** | International Union of Biological Sciences |
| **IUCN** | World Conservation Union |
| **LAMP** | Latin American Maize Project |
| **MAB** | Man and the Biosphere Programme (UNESCO) |
| **MARDI** | Malaysian Agricultural Research and Development Institute |
| **MASIPAG** | Farmer-Scientist Partnership for Development Association (the Philippines) |
| **MESFIN** | Mediterranean Fruit Inter-country Network |
| **MTA** | material transfer agreement |
| **NAA** | Non-Agriculture Association (NGO, Thailand) |
| **NARS** | National Agricultural Research Systems |
| **NBPGR** | National Bureau of Plant Genetic Resources (India) |
| **NGB** | Nordic Gene Bank |
| **NGO** | non-governmental organization |
| **NPGRC** | National Plant Genetic Resources Centres |
| **NPGRL** | National Plant Genetics Resources Laboratory (the Philippines) |
| **NPGS** | National Plant Germplasm System (United States) |
| **NIAR** | National Institute of Agrobiological Resources, Japan |

| | |
|---|---|
| **NSSL** | National Seed Storage Laboratory (USDA-ARS) |
| **NTAE** | non-traditional agricultural export |
| **ODI** | Overseas Development Institute (United Kingdom) |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OECS** | Organization of Eastern Caribbean States |
| **OPV** | open-pollinated varieties |
| **ORSTOM** | Institut français de recherche scientifique pour le développement en coopération |
| **PBR** | plant breeders' rights |
| **PCR** | polymerase chain reaction |
| **PGRFA** | plant genetic resources for food and agriculture |
| **PRAPACE** | Potato and Sweet Potato Improvement Network for Central and Eastern Africa |
| **PROCISUR** | Programa Cooperativo para el Desarrollo Tecnológico Agropecuario del Cono Sur |
| **PROSEA** | Plant Resources of South East Asia |
| **PVP** | plant variety protection |
| **QTL** | quantitative trait loci |
| **RAFI** | Rural Advancement Foundation International |
| **RAPD** | random amplified polymorphic DNA |
| **RBG** | Royal Botanic Gardens (Kew, United Kingdom) |
| **RDA** | Rural Development Administration (Republic of Korea) |
| **RECSEA** | Regional Committee for Southeast Asia |
| **RECSEA-PGR** | Regional Collaboration in Southeast Asia on Plant Genetic Resources |
| **REDARFIT** | Andean Network of Plant Genetic Resources |
| **REDBIO** | Technical Cooperation Network on Plant Biotechnology |
| **REMERFI** | Central American Network of Plant Genetic Resources |
| **RESAPAC** | Great Lakes Regional Bean Programme |
| **RFLP** | restriction fragment length polymorphism |
| **ROCAFREMI** | Reseau ouest et central africain de recherche sur le Mil |

| | |
|---|---|
| **ROCARS** | Reseau ouest et central africain de recherche sur le Sorgho |
| **RS** | Recurrent selection |
| **SACCAR** | Southern African Centre for Cooperation in Agricultural Research |
| **SADC** | Southern African Development Community |
| **SAPPRAD** | Southeast Asian Programme for Potato Research and Development |
| **SCOPE** | Scientific Committee on Problems of the Environment |
| **SEANUC** | Southern and Eastern African Network on Under-utilized Crops |
| **SEARICE** | South East Asian Institute for Community Education (NGO, the Philippines) |
| **SELA** | Sistema económico latinoamericano |
| **SGRP** | System-wide Genetic Resources Programme (of CGIAR) |
| **SIDA** | Swedish International Development Authority |
| **SINGER** | System-wide Information Network on Genetic Resources |
| **SPC** | South Pacific Commission |
| **SPGR** | System-wide Programme on Genetic Resources |
| **SPGRC** | SADC Plant Genetic Resources Centre |
| **SPREP** | South Pacific Regional Environment Programme |
| **TREE** | Technology for Rural and Ecological Enrichment (NGO, Thailand) |
| **TRIPs** | trade-related aspects of intellectual property rights |
| **TROPIGEN** | Amazonian Network of Plant Genetic Resources |
| **UFTANET** | Under-utilized Tropical Fruit Trees Network |
| **UK** | United Kingdom |
| **UN** | United Nations |
| **UNCED** | United Nations Conference on Environment and Development |
| **UNCTAD** | United Nations Conference on Trade and Development |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |

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|---|---|
| **UNIDO** | United Nations Industrial Development Organization |
| **UPOV** | International Union for the Protection of New Varieties of Plants |
| **UPWARD** | User's Perspective with Agricultural Research and Development |
| **USA** | United States of America |
| **USDA/ARS** | United States Department of Agriculture/ Agricultural Research Service |
| **USSR** | Union of Soviet Socialist Republics |
| **VIR N.I.** | Vavilov Institute (Russian Federation) |
| **WANANET** | West Asia and North Africa Plant Genetic Resources Network |
| **WARDA** | West Africa Rice Development Association |
| **WIEWS** | FAO World Information and Early Warning System on Plant Genetic Resources |
| **WIPO** | World Intellectual Property Organization |
| **WMO** | World Meteorological Organization |
| **WRI** | World Resources Institute |
| **WTO** | World Trade Organization |
| **WWF** | World Wide Fund for Nature |

[1] Additional acronyms of institutions referred to in Annex 2 and Appendix 2 are presented in Appendix 2.

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OF THIS BOOK IS OVER.

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# Preface

Plant genetic resources for food and agriculture (PGRFA) are the biological basis of world food security and, directly or indirectly, support the livelihoods of every person on earth. 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 as food, and as feed for domestic animals, fibre, clothing, shelter, wood, timber, energy, etc. These resources are the raw material used in the production of new cultivars - either through traditional plant breeding or through biotechnology. Whether used directly by farmers as a raw material or by plant breeders, PGRFA are a reservoir of genetic adaptability which acts as a buffer against potentially harmful environmental and economic change. The erosion of these resources poses a severe threat to the world's food security in the long term. Although often undervalued, the urgent need to conserve and utilize PGRFA as a safeguard against an unpredictable future is clear.

Today, access to food around the world is not secure.[1] 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. Reliable and sustainable improvements in yield will be needed to meet the demands of this growing population. The conservation and sustainable utilization of plant genetic resources are the keys to improving agricultural productivity and sustainability, thereby contributing to national development, food security and the alleviation of poverty.

Recognizing the importance of PGRFA, the Conference of the Food and Agriculture Organization of the United Nations (FAO), at its Twenty-sixth Session in 1991, agreed that a first Report on the State of the World's Plant Genetic Resources for Food and Agriculture should be developed. The report would describe the current situation of plant genetic resources for food and agriculture at the global level, and identify what is required to ensure their conservation and sustainable utilization, thereby laying the foundation for a Global Plan of Action. It was agreed that a Report on the State of the World's PGRFA and a Global Plan of Action — both components of the FAO Global System on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture[2] — would be developed through a country-driven process in preparation for the International Technical Conference on Plant Genetic Resources.[3]

### The historical context

While plant genetic resources have been sought after, collected, used and improved for centuries, it has only been since the 1930s that official concern has been voiced regarding the need for conservation. International efforts initiated through FAO to promote conservation, exchange and utilization, are more recent.

FAO started a newsletter on plant genetic resources in 1957[4] and, beginning in 1961, convened a series of technical meetings and conferences.[5] In 1963, an FAO Panel of Experts on Plant Exploration was established to advise the Organization and set international guidelines for the collection, conservation and exchange of germplasm. A similar Panel of Experts was created for forest genetic resources in 1968. In general, FAO acted as a catalyst for action in response to what was widely perceived as an emergency situation.

In the context of the growing alarm over the rapid loss of diverse farmer landraces, the Consultative Group on International Agricultural Research (CGIAR) established the International Board for Plant Genetic Resources (IBPGR)[6] in 1974, as an independent board with a secretariat supplied by FAO. IBPGR's mission was to coordinate an international plant genetic resources programme. Collecting missions were accelerated, and genebanks were constructed and expanded at national, regional and international levels.

While much was accomplished in the 1970s and 1980s, gaps persisted in the practical conservation work itself and in the linkages with utilization efforts. Institutional relations and policy matters were also in need of attention. Due in large part to the urgency of the work during this period, no systematic attempt was made at an intergovernmental level to develop a comprehensive, coordinated plan to conserve and sustainably utilize plant genetic resources.

In 1983, the FAO Conference established the intergovernmental Commission on Plant Genetic Resources[7] and adopted a non-binding International Undertaking on Plant Genetic Resources. The latter is now being revised by the Commission in light of the Convention on Biological Diversity. The Undertaking and the Commission are the main institutional components of the Global System on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture. The Global System also includes other international agreements, technical mechanisms and global instruments at different stages of development. In 1989, the FAO Conference adopted the concept of Farmers' Rights as part of the International Undertaking.[8]

By the early 1990s, it was becoming increasingly evident that an intergovernmental conference was needed to assess progress, identify problems and opportunities, and help give direction to future activities in the conservation and utilization of plant genetic resources for food and agriculture.

The convening of this International Technical Conference on Plant Genetic Resources was first proposed in 1991 by the FAO Commission on Plant Genetic Resources at its Fourth Session, and was endorsed by the FAO Conference at its Twenty-sixth Session of the same year. Also in 1991, the FAO Conference agreed that Farmers' Rights should be implemented through an international fund.

A scientifically sound and costed Global Plan of Action would be required to guide funding priorities. In turn, the Global Plan of Action would be based on a first Report on the State of the World's Plant Genetic Resources. It was agreed that this Report and the Plan of Action be developed through the preparatory process for the International Technical Conference on Plant Genetic Resources, and presented to that body for its consideration.

In June 1992, the importance of plant genetic resources was recognized at the United Nations Conference on Environment and Development (UNCED). In particular, Chapter 14 of Agenda 21 includes a programme area on the "conservation and sustainable utilization of plant genetic resources for food and sustainable agriculture". At the international level, Agenda 21 proposes actions to strengthen the FAO Global System, including:

a) the preparation of periodic reports on the state of the world's PGRFA;
b) the preparation of a rolling global cooperative Plan of Action on PGRFA and the promotion of the International Technical Conference which would consider the first Report on the State of the World's Plant Genetic Resources and the Plan of Action.

At its Fifth Session, in April 1993, the Commission noted that the International Technical Conference process would "transform the relevant parts of the UNCED process (including Agenda 21 and the Convention on Biological Diversity) into a costed Global Plan of Action based on the Report on the State of the World's Plant Genetic Resources". The Commission also noted that the process would "make the Global System for the Conservation and Use of Plant Genetic Resources fully operational". Later, in 1993, the Twenty-seventh Session of the FAO Conference strongly emphasized the importance of the Fourth International Technical Conference and endorsed its aims and strategy.

### The preparatory process for the International Technical Conference

The State of the World's Plant Genetic Resources was developed through a participatory, country-driven process under the guidance of the Commission on Genetic Resources for Food and Agriculture.[9] FAO established a multi-donor trust fund project, the International Conference and Programme for Plant Genetic Resources, to coordinate the preparatory process for the International Technical Conference including the preparation of the Report on the State of the World's Plant Genetic Resources (the shorter version of this publication) and a draft Global Plan of Action for consideration by the Conference.[10] One hundred and fifty-seven countries were actively involved in the preparatory process (see Appendix 1).[11] Over 50 non-governmental organizations, including private sector associations, were also actively involved.[12]

Country Reports, based on guidelines prepared by FAO,[13] were submitted by 154 countries (see Appendix 1).[14] In separate chapters within these reports, countries assessed their situation with regard to indigenous plant genetic resources, national conservation activities (*ex situ* and *in situ*), in-country uses of plant genetic resources, national goals, policies, programmes and legislation, and international collaboration. In addition, countries identified national needs and opportunities, and made specific proposals for the Global Plan of Action. The 154 Country Reports provided a large amount of information and a sound foundation for the critical assessment of the status of plant genetic resources and existing capacities to conserve and utilize them. In fact, Country Reports were the primary source of data of this publication. Care has been taken in using and compiling the information provided; examples drawn from the Country Reports are included for illustrative purposes only and are not meant to be exclusive or 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.[15]

The Secretariat for the International Technical Conference, which prepared "The State of the World's Plant Genetic Resources", was also able to draw upon information from the database of the FAO World Information and Early Warning System, assembled from the responses of 89 countries to two FAO questionnaires,[16] and from information from 79 countries provided in response to a separate questionnaire on forest genetic resources. In addition, a number of international agricultural research centres of CGIAR provided information.

The Secretariat also had access to the findings of the recently completed external review of centre genebanks. Additionally, over 200 individual scientists contributed their recommendations, largely through FAO's electronic conferences on plant breeding and genetic diversity which were set up for the purpose.[17]

Based on the Country Reports and visits by Secretariat staff and consultants to more than 100 countries, 15 sub-regional synthesis reports were prepared. These reports provided the basis for discussions at most of the 12 regional and sub-regional meetings held between July 1995 and 1996 (see table below). These meetings and the preparation of Country Reports benefited greatly from technical assistance and logistic support provided by the International Plant Genetic Resources Institute (IPGRI). A total of 143 countries and a number of international and non-governmental organizations participated in the intergovernmental regional and sub-regional preparatory meetings. Each meeting formulated and adopted recommendations for the Global Plan of Action which are reflected in the analysis and conclusions contained in this volume.

During the 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. FAO also benefited significantly from the assistance of individual centres of the Consultative Group on International Agricultural Research (CGIAR), and IPGRI, in particular. Three workshops concerning forest genetic resources were held: one for the forest genetic resources of Europe,[18] another on the boreal zone,[19] and a third on the temperate zone of North America.[20] Additional workshops in support of the preparatory process were held on molecular genetic techniques,[21] regeneration,[22] *in vitro* conservation and field genebanks,[23] participatory plant breeding[24] and the valuation of genetic resources.[25]

**Preparatory Meetings for the International Technical Conference**

| Sub-Regions[26] | Location | Date |
|---|---|---|
| East Asia | Beijing, China | 24-26 July 1995 |
| Central America, Mexico, the Caribbean | San José, Costa Rica | 21-24 August |
| South America | Brasilia, Brazil | 28 Aug - 1 September |
| East Africa and the Indian Ocean | Nairobi, Kenya | 12-14 September |
| Southern Africa | Kadoma, Zimbabwe | 19-21 September |
| Europe (Western and Eastern) | Nitra, Slovakia | 24-27 September |
| South Asia, Southeast Asia and Pacific | Bangkok, Thailand | 3-6 October |
| West and Central Asia | Tehran, Islamic Rep. of Iran | 9-12 October |
| Mediterranean* | Tunis, Tunisia | 16-19 October |
| West and Central Africa | Dakar, Senegal | 27-30 November |
| North America | Ottawa, Canada | 7-8 December |
| Latin America and the Caribbean** | Bogotá, Colombia | 18-22 March 1996 |

* The Mediterranean meeting included countries from the South and East Mediterranean and the southern countries of Europe.

** This regional meeting was additional to the sub-regional meetings, which considered Synthesis Reports.

The second meeting of the Conference of the Parties to the Convention on Biological Diversity in 1995 affirmed its support for the Fourth International Technical Conference and described its preparatory process as "innovative" and "exemplary".

### The International Technical Conference on Plant Genetic Resources

The Fourth International Technical Conference on Plant Genetic Resources was convened by FAO and held in Leipzig, Germany, from 17 to 23 June 1996, and was attended by representatives of 150 countries. The Conference welcomed the Report on the State of the World's Plant Genetic Resources as the first comprehensive worldwide assessment of the state of plant genetic resource conservation and use. The Conference also adopted a "Leipzig Declaration" and the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture.

Subsequently, the FAO Council, and the Conference of the Parties to the Convention on Biological Diversity welcomed the outcome of the International Technical Conference, and the World Food Summit, convened in Rome in November 1996, called for the implementation of the Global Plan of Action.

The 75-page report submitted formally to the International Technical Conference was based upon and supplemented by a 336-page background study, The State of the World's Plant Genetic Resources, which forms the basis of the present volume. Following the International Technical Conference, this background study was sent for peer review to a number of the world's leading authorities on various aspects of PGRFA. The present volume, "The State of the World's Plant Genetic Resources", is a result of the preparatory process for the International Technical Conference, as well as of peer review, editing and updating.

### Organization of this volume

Chapter One, entitled "The state of diversity", provides information on the range of crops and other plant species important for food security, the origins and value of PGRFA, and an assessment of the state of genetic vulnerability and genetic erosion.[27] More detailed information on the state of diversity of particular crops is provided in Annex 2.

Chapters Two to Six provide an assessment of "the state of capacity" for conservation and utilization of plant genetic resources. Chapter Two examines *in situ*, including on-farm, management of PGRFA, while Chapter Three discusses *ex situ* conservation. Chapter Four covers utilization, including evaluation, genetic enhancement, plant breeding and seed activities, with an emphasis on the linkages between conservation and utilization. Institutional aspects are covered in the next two chapters: Chapter Five looks at national programmes, legislation and training needs, while Chapter Six reviews cooperation at the regional and global levels. Chapter Seven examines the issues of access to genetic resources, the sharing of benefits derived from their use and the realization of Farmers' Rights. At the end of each chapter, there is a short concluding section which provides an assessment of major needs.

Annex 1 reviews "The State of the Art" of techniques and other methodologies required for the conservation and sustainable utilization of PGRFA. Background data are provided in the Appendices as well as in the figures and tables in each chapter.

**A periodic publication**

It is intended that FAO periodically assess the State of the World's Plant Genetic Resources. As a component of the Global System, such reports will allow the Commission on Genetic Resources for Food and Agriculture to monitor global efforts and identify gaps, constraints and emergency situations in the conservation and sustainable utilization of PGRFA. Periodic assessments would be closely linked to the World Information and Early Warning System, and would provide the basis for the rolling Global Plan of Action.

While every effort has been made to provide an accurate and complete assessment of the state of the world's plant genetic resources in the first report, it necessarily reflects the limitations of the sources of information. Despite the large amount of information generated and assembled during the preparatory process for the International Technical Conference, gaps and deficiencies remain. It is expected that these limitations will be progressively overcome in future editions.

The current volume, the first publication of its kind by FAO, should therefore be of assistance in revealing these gaps and helping to create awareness of what is still not known or sufficiently understood. In addition, it should provide a benchmark against which future progress may be measured.

## Preface endnotes

[1] McCalla AF (1994) Agriculture and food need to 2025: why we should be concerned. Sir John Crawford Memorial Lecture, CGIAR International Centres Week, 27 October 1994, Washington DC.

[2] The Global System, being developed by FAO, has the objectives of promoting the conservation, availability and sustainable utilization of plant genetic resources for present and future generations, by providing a flexible framework for sharing the benefits and burdens. One hundred and seventy-one countries and the European Community participate in the Global System. A more complete description of the Global System is found in Chapter 6. and in Document CPGR-6/95/4 of the Commission on Plant Genetic Resources, *Progress Report on the Global System for the Conservation and Use of Plant Genetic Resources for Food and Agriculture*.

[3] The preparation of a Report on the State of the World's Plant Genetic Resources for Food and Agriculture and its adoption at the International Technical Conference was also recommended by the United Nations Conference on Environment and Development (UNCED) in its Agenda 21 (paragraph 14.60 (c)) and supported by the Conference of the Parties to the Convention on Biological Diversity (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).

[4] This newsletter has continued to be published since 1957. Today, it is published jointly by FAO and IPGRI under the title *Plant Genetic Resources Newsletter*.

[5] A series of international technical conferences and meetings on plant genetic resources have been convened by FAO, in cooperation with other organizations, to facilitate technical discussions among scientists, and to create awareness about plant genetic resources issues among policy-makers at national and international levels. The first significant meeting took place in 1961 and focused on plant exploration and introduction. The 1967 Conference formulated a number of important resolutions subsequently adopted by the 1972 UN Conference on the Human Environment, in Stockholm. A 1973 Conference interpreted the resolutions of the Stockholm Conference in the context of plant genetic resources. The international technical conference that took place in 1981 catalysed the development of the FAO Global System on the Conservation and Sustainable Use of Plant Genetic Resources.

[6] The International Plant Genetic Resources Institute (IPGRI) is the legal successor to IBPGR.

[7] The scope of the Commission was broadened by the FAO Conference at its Twenty-eighth Session in 1995 (Resolution 3/95) to become the Commission on Genetic Resources for Food and Agriculture.

[8] FAO Conference Resolution 5/89.

[9] Op. cit., endnote 7.

[10] A total of about USò 5.5 million was contributed by Germany, the United States, Sweden, the Netherlands, France, Switzerland, Japan, Italy, Norway and Spain for the preparatory process and developing country participation in the Conference. Substantial in-kind contributions have also been made by Canada, Brazil, the Islamic Republic of Iran, Slovakia and the Nordic countries. IPGRI also made substantial in-kind contributions.

[11] This number includes countries that submitted a Country Report, or participated in one of the subregional meetings, or nominated a focal point for the process, or any combination of the above (see Appendix 1). Focal points were designated by 150 countries to coordinate national preparations and liaise with the FAO Secretariat.

12 Twenty-nine participants from 17 countries participated in the NGO seminar "NGOs and biodiversity: moving from basic agreement to concrete action and justice", organized by the Dag Hammarskjöld Foundation in February 1995. A number of NGOs also participated in subregional preparatory meetings.

13 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 or standardized quantitative data.

14 *The State of the World's Plant Genetic Resources for Food and Agriculture* is based on Country Reports from the following 154 countries: Albania, Angola, Antigua and Barbuda, Argentina, Armenia, Austria, Azerbaijan, Bahamas, Bangladesh, Barbados, Belarus, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chile, China, Colombia, Congo, Cook Islands, Costa Rica, Côte d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Democratic People's Republic of Korea, Denmark, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Finland, France, Gabon, Gambia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iraq, Ireland, Islamic Republic of Iran, Israel, Italy, Jamaica, Japan, Jordan, Kazakhastan, Kenya, Latvia, Lebanon, Lesotho, Libyan Arab Jamahiriya, Lithuania, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, the Netherlands, Nicaragua, the Niger, Nigeria, Niue, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, the Philippines, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Romania, Rwanda, Russian Federation, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Slovakia, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, the Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Kingdom, United Republic of Tanzania, United States of America, Uruguay, Uzbekistan, Venezuela, Viet Nam, Yemen, Federal Republic of Yugoslavia (Serbia and Montenegro), Zaire, Zambia, Zimbabwe. Reports were subsequently received from Australia, Bhutan, Kuwait, New Zealand and Palestine.

15 For example, of the 151 Country Reports examined, 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. Many Country Reports were provided to the Secretariat initially in draft form, giving the Secretariat an opportunity to communicate from Country Reports and other information generated during the preparation of *The State of the World's Plant Genetic Resources for Food and Agriculture.* Refer to Chapter 6 for more information.

16 As agreed by the Commission the WIEWS has been updated using information from Country Reports and other information generated during the preparation of *The State of the World's Plant Genetic Resources for Food and Agriculture.* Refer to Chapter 6 for more information.

[17] A list of acknowledgements is found after the Contents.

[18] The European Forest Genetic Resources Workshop, sponsored by FAO and IPGRI, Sopron, Hungary, 21 November 1995.

[19] International Workshop on the Genetic Resources of Boreal Zone Forest Species, organized by the Petatawa National Institute of the Canadian Forest Service, in technical collaboration with FAO, Toronto, Canada, 19-22 June 1995.

[20] Workshop on Conservation of Forest Genetic Resources of the North American Temperate Zone, organized by the Institute of Forest Genetics, Pacific Southwest Research Station of the USDA Forest Service, in technical collaboration with FAO, Berkeley, California, USA, 12-14 June 1995.

[21] IPGRI Workshop on Molecular Genetic Techniques for Plant Genetic Resources, Rome, 9-11 October 1995.

[22] Consultation on the Regeneration of Germplasm of Seed Crops and their Wild Relatives, sponsored by FAO, ICRISAT, IPGRI and SGRP, ICRISAT Asia Center, Patancheru, India, 4-7 December 1995.

[23] Consultation on the Management of Field and *in vitro* Genebanks, sponsored by CIAT, FAO, IPGRI and SGRP, Cali, Colombia, 15-20 January 1996.

[24] Workshop on Participatory Plant Breeding, Wageningen, the Netherlands, 26-29 July 1995, sponsored by IDRC, IPGRI, FAO and the Centre for Genetic Resources of the Netherlands.

[25] Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, sponsored by the Centre for International Studies on Economic Growth, Tor Vergata University of Rome and FAO, Rome, 13-15 May 1996.

[26] The following were represented at the meetings:

East Asia (China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea);

Central America, Mexico and the Caribbean (Antigua and Barbuda, Bahamas, Barbados, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Granada, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago);

South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Suriname, Uruguay, Venezuela);

East Africa and the Indian Ocean (Burundi, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Seychelles, the Sudan, Uganda);

Southern Africa (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, United Republic of Tanzania, Zambia, Zimbabwe);

Europe (Austria, Belarus, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Moldova, the Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom);

South Asia, Southeast Asia and the Pacific (Bangladesh, Cambodia, India, Indonesia, Malaysia, Maldives, Myanmar, Nepal, Papua New Guinea, the Philippines, Solomon Islands, Sri Lanka, Thailand, Tonga, Viet Nam, Samoa);

Central and West Asia (Azerbaijan, Iraq, the Islamic Republic of Iran, Kazakhstan, Pakistan, Turkey, Turkmenistan, Uzbekistan, Yemen);

> Mediterranean (Cyprus, Egypt, European Community, France, Italy, Jordan, Israel, Lebanon, Morocco, Portugal, Spain, the Syrian Arab Republic, Tunisia);

West and Central Africa (Benin, Burkina Faso, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Mali, Mauritania, the Niger, Nigeria, Senegal, Sierra Leone, Togo, Zaire);

North America (Canada, United States);

Latin America and the Caribbean (Antigua and Barbuda, Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Grenada, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela).

[27] The outline and overall contents of the Report were agreed by the Commission on Plant Genetic Resources at its Sixth Session. See also FAO (1995) Outline of the Report on the State of the World's Plant Genetic Resources for Food and Agriculture, paper prepared for the Sixth Session of the Commission on Plant Genetic Resources, CPGR-6/95/10.

# CHAPTER 1
# The State of Diversity

## 1.1 INTRODUCTION

Plant genetic resources for food and agriculture (PGRFA) comprise the diversity of genetic material contained in traditional varieties and modern cultivars, as well as crop wild relatives and other wild plant species that can be used now or in the future for food and agriculture. [1]

The precise delimitation of PGRFA as a distinct part of biodiversity is difficult. These resources may be described as "that part of biodiversity that nurtures people and that is nurtured by people". Broadly defined, PGRFA include resources which contribute to people's livelihoods by providing food, medicine, feed for domestic animals, fibre, clothing, shelter and energy, etc. Here, emphasis is given to the PGRFA which contribute most to food security.[2]

This first Chapter provides an introduction to the state of PGRFA. The following aspects are considered:

- the range of crops and other plant species important for food security, and the diversity within these (the state of diversity of selected major crops and underutilized species is provided in Annex 2);
- the centres of origin and diversity of PGRFA, the history of their distribution, and the interdependence between countries for PGRFA;
- the usefulness and value of PGRFA and diversity itself, both for small farmers and as inputs in the breeding of modern varieties;
- genetic vulnerability which can result from excessive genetic uniformity in crops and the loss of genetic resources through genetic erosion.

Better utilization of PGRFA will contribute to agricultural development, food security and the alleviation of poverty. The challenge of promoting both conservation of PGRFA and their sustainable utilization to meet these objectives is briefly reviewed in the final section of the Chapter.

# 1.2 DIVERSITY WITHIN AND BETWEEN PLANT SPECIES

## 1.2.1 The diversity of plant species

It has been estimated that there are between 300,000 and 500,000 species of higher plants (i.e. flowering and cone-bearing plants), of which approximately 250,000 have been identified or described.[3] About 30,000 are edible and about 7,000 have been cultivated or collected by humans for food at one time or another.[4] Thus, several thousand species may be considered to contribute to food security.

### Major crops

It is often stated, however, that only 30 crops "feed the world" (see Figure 1.1).[5] These are the crops which provide 95% of dietary energy (calories) or protein. Figure 1.2 shows that wheat, rice and maize alone provide more than half of the global plant-derived energy intake. These three crops have received the most investment in terms of conservation and improvement. A further six crops or commodities, sorghum, millet, potatoes, sweet potatoes, soybean and sugar (cane/beet), bring the total to 75% of the energy intake. This information is based on data for national food energy supplies aggregated at the global level.[6]

**Estimated numbers of food crop species**

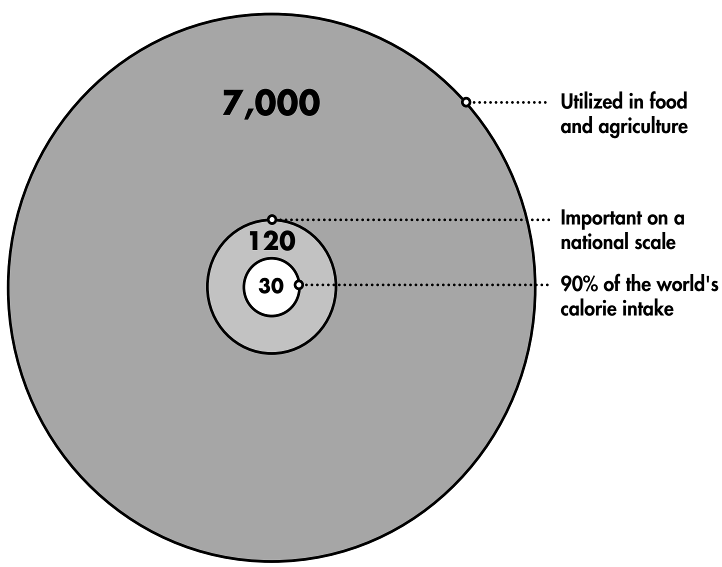



Figure 1.1

When food energy supplies are analysed at the sub-regional level, however, a greater number of crops emerge as significant (Figure 1.3). For example, cassava supplies over half of plant-derived energy in Central Africa, although at a global level the figure is only 1.6%. Beans and plantain also emerge as very important staples in certain sub-regions. These major food crops, as well as others such as groundnut, pigeon pea, lentils, cowpea and yams, are the dietary staples of millions of the world's poorer people, although they receive relatively little research and development attention.[7]

## Most important crops for food energy supply

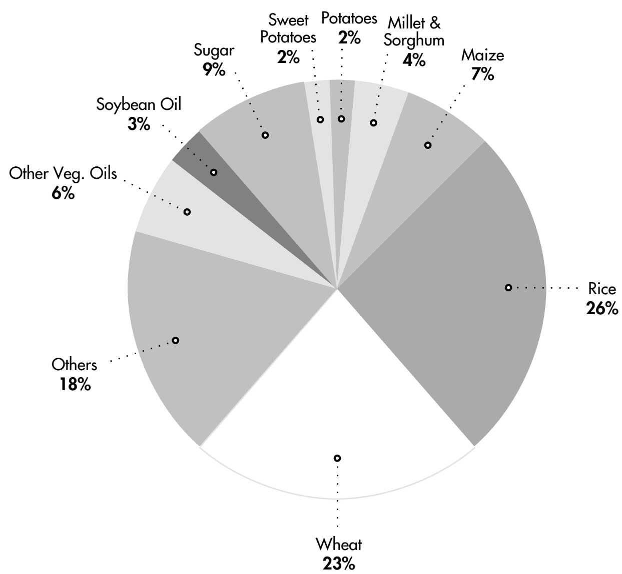



Figure 1.2

*Source:* FAO Food Balance Sheets, 1984-1986, Rome (1991)

Analysis of food energy supplies on a country by country basis shows that 90% of the per caput food plant supplies of all nation states are provided by only 103 plant crops.[8] Yet there are many other species that are important to large numbers of people at sub-national levels, which fall outside the list when aggregated at a national level. These include local staples such as oca, teff, fonio or bambara groundnut, all of which tend to be neglected in terms of conservation and crop improvement programmes (see next sub-section on minor crops). In addition, a large number of crops are important as suppliers of other dietary factors (protein, fats, vitamins and minerals, etc.).

Given the importance of a relatively small number of crops for global food security, it is particularly important that the diversity within major crops is conserved effectively, available for use, and managed wisely. Annex 2 provides a crop by crop review of the state of diversity for the following crops, each of which supply more than 5% of plant-derived energy intake at the sub-regional level: wheat, rice, maize, millet, sorghum, potatoes, soybean, sugar cane,[9] sweet potatoes, cassava, beans (*Phaseolus*)[10] and banana/plantain (*Musa*). It should be noted that a substantial share of energy intake is also provided by meat which is ultimately derived from forage and rangeland plants. These crops are also reviewed in Annex 2.

**Minor crops and underutilized species**

The terms "minor crops" and "underutilized species" are used variously to refer to plants which fulfil a wide range of functions. These plants are listed below:

- Staple crops for specific regions or localities. Such "minor staples" include various species of yam, proso millet, fonio ("hungry rice"), bambara groundnut, oca, taro/cocoyam, canihua, breadfruit, *Amaranthus*, quinoa, acanyt and buckwheat. (The South American sub-regional meeting identified "contribution to food security" as an important criterion in allocating resources to crops.[11])
- Vegetables, fruits and other species, including wild plants and "weeds" gathered for food which contribute to nutrition and dietary diversification.[12] (The Caribbean meeting, held as part of the preparatory process to the International Technical Conference, specifically referred to the importance of local vegetable species which contribute to nutrition and health.[13])
- Multipurpose trees, including trees managed in agroforestry systems and wild species that are harvested.[14]
- Crops that can contribute to agricultural diversification including uncultivated or little cultivated species with alimentary or agricultural potential.[15]

There is often a lack of knowledge about the diversity and distribution of less utilized food and agriculture species.[16] The need for more attention to such minor or underutilized crops in conservation and utilization programmes was identified at all of the sub-regional meetings held in preparation for the International Technical Conference.

The countries of the West and Central African sub-regions, for example, identified a large number of underutilized species that are important to the livelihoods of local populations, including cereals (7 species), legumes (8), roots and tubers (4), oil crops (8), fruits and nuts (31), vegetables and spices (17), beverages (4), medicinal plants (38) and 44 genera of forages.[17]

## Main staple food supply in the subregions of the world

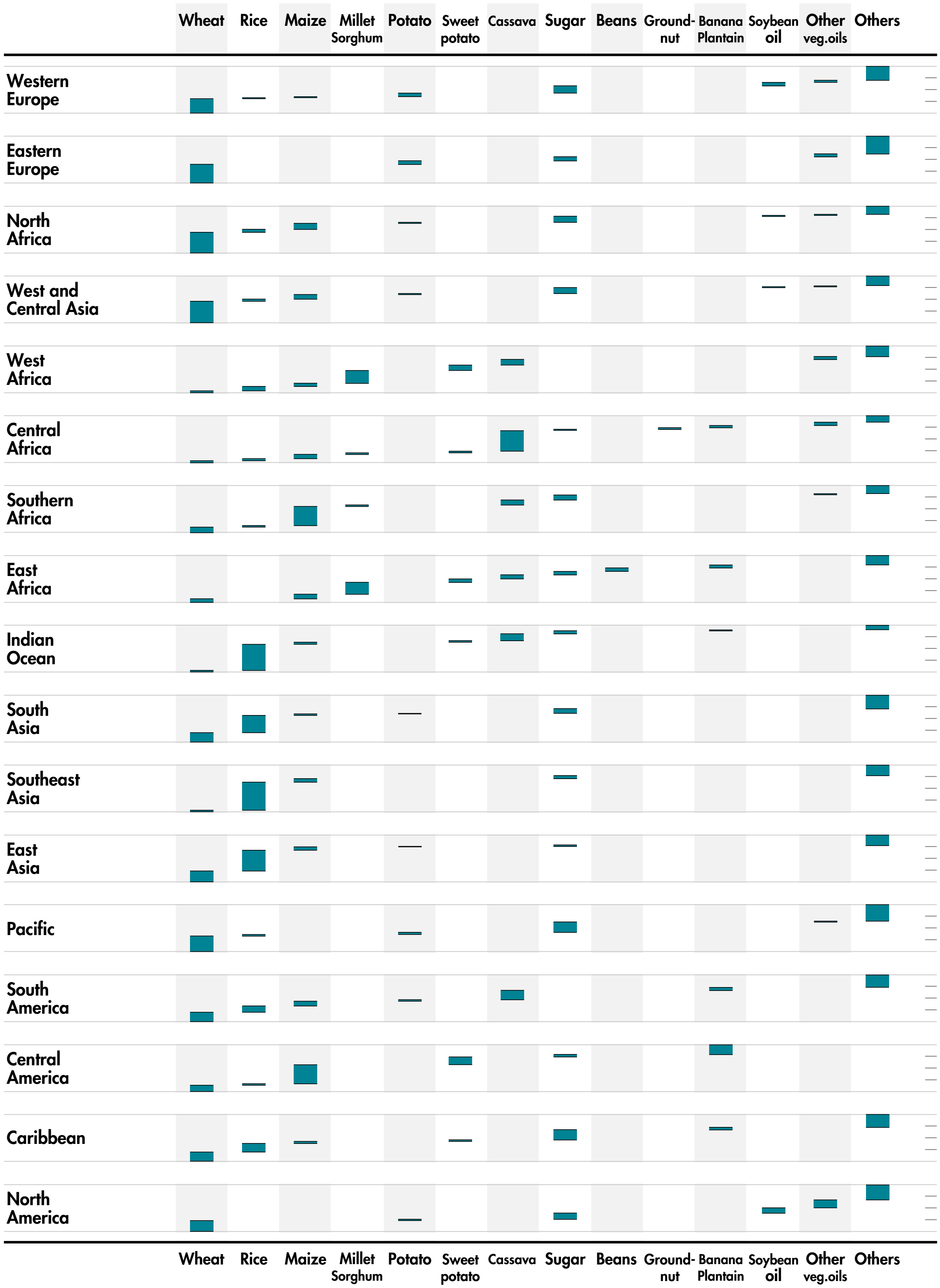



Figure 1.3

*Source:* FAO Food Balance Sheets, 1984-1986, Rome (1991)

Given the importance of underutilized species, it was suggested that when priorities are set according to species, consideration be given to underutilized species as a group in order to avoid their further marginalization. Table 2.1 in Annex 2 also provides information on the conservation and utilization status of a selection of minor crops and underutilized species, including the minor staples listed above.

#### Wild species

Wild species[18] are important, both nutritionally and culturally, to many people. A number of countries report the use of wild food during periods of famine and especially during the hunger season that precedes crop harvests.[19] Such foods form an integral part of the daily diets of many poor rural households. Wild foods are a source of important vitamins, minerals and other nutrients which complement the staple crops eaten by many of the most vulnerable people, including children and the elderly.[20] The importance of a wide range of wild species, including roots and tubers, leafy vegetables and fruits is recorded in many Country Reports[21] and Sub-regional Synthesis Reports.[22] Such wild resources also represent ready sources of income for cash-poor households and may provide a significant proportion of total household income, particularly where farming is marginal. For instance, in the United Republic of Tanzania in 1988, it was calculated that the value of all wild plant resources to rural communities, whether for subsistence consumption or sale, was more than US ò120 million (8% of agricultural GDP).[23] Wild species which are related to crops are also important as resources for crop improvement, and often as useful species in their own right, e.g. forage grasses.

### 1.2.2 Diversity within species

While the number of plant species which supply most of the world's energy and protein is relatively small, the diversity within such species is often immense. Estimates of the number of distinct varieties of the rice species, *Oryza sativa*, range from tens of thousands to more than 100,000. At least seven different vegetables derive from the single wild cabbage species *Brassica oleracea* (kale, cauliflower, cabbage, Brussels sprouts, kohlrabi, broccoli calabrese, savoy cabbage). Genetic variation also exists within these vegetables and numerous different varieties of each can be found.

#### Crop varieties

For the purpose of this report, cultivated varieties can be broadly classified into "modern varieties" and "farmers' varieties". Modern varieties are the products of plant breeding in the formal system (sometimes called "scientific breeding") by professional plant breeders working in private companies or publicly-funded research institutes. These varieties are sometimes called "high-yielding varieties" (HYVs) or high-response varieties. They typically have a high degree of genetic uniformity and, except for F1 hybrids and synthetic or composite varieties, they breed true.

Farmers' varieties, otherwise known as landraces or traditional varieties, on the other hand, are the product of breeding or selection carried out by farmers, either deliberately or not, continuously over many generations. Farmers' varieties tend not to be genetically uniform[24] and contain high levels of genetic diversity.[25] These varieties, therefore, may be difficult to define or distinguish unequivocally as a particular variety (see Annex 1-1). Landraces, however, may be recognized morphologically. Farmers have names for them and different landraces are understood to differ in adaptation to soil type, time of seeding, date of maturity, height, nutritive value, use and other properties.[26] Landraces, because of their genetic diversity, are the focus of most conservation efforts.

The inherent variation within farmers' varieties, or landraces, is especially high for cross-pollinated species such as maize and millet. This is particularly important for optimizing output from highly variable environments. For self-pollinated crops such as rice, wheat and barley, however, and for vegetatively propagated crops such as potatoes and bananas, individual varieties are less variable, but the number of varieties developed may be very high. For example, the Arguarana Jivaro community in the Peruvian Amazon grows 61 distinct cultivars of cassava, while some small communities in the Andes grow as many as 178 locally named potato varieties.[27]

## 1.3 ORIGINS OF PGRFA AND THE INTERDEPENDENCE OF COUNTRIES ON PGRFA

### Centres of origin and diversity

For each crop there are one or more centres of origin where the crop was domesticated.[28] These are usually the primary centres of *in situ* diversity for that crop and continued geneflow between crops and their wild relatives in these areas can contribute to new variability. Centres of diversity do not always correspond to the area where the crop was domesticated. Centre of origin is not a synonym, in other words, for centre of diversity. Moreover, particular varieties of crop may have originated outside both centres of origin and diversity. In addition, in many cases, centres of origin are difficult to define. Different species of the same crop may have been domesticated in different places. For example, different species of yams were domesticated in West Africa, Southeast Asia and tropical America. There are also examples of the independent domestication of the same species of the crop in various places, both cassava and sweet potato being domesticated independently, perhaps in Central and South America,[29] and *Phaseolus vulgaris* being domesticated in Mesoamerica and South America. As noted below, secondary centres of diversity are also very important for some crops, thus making these areas particularly important for conservation.

For many crops, the centres of origin and areas of high diversity are located in developing countries. Whilst in the context of biodiversity conservation, tropical forests are the areas singled out for their rich diversity, drier ecosystems are, on the whole, far more important for crop resources. The Russian plant explorer, N.I. Vavilov, first noted that diversity of domesticated crops was not uniformly distributed around the world. It tended to be found in certain areas, which typically shared certain geographic characteristics and a history of ancient times settlement and agricultural practices. It is worth noting that many of these very areas, e.g. the Near East and Central Asia, are semi-arid and mountainous and are for the most part, agriculturally marginal with respect to soil fertility, water, etc. They are also the regions where many resource-poor farmers are located. Figure 1.4 illustrates the centres of genetic diversity for some crops (refer to Appendix 3 for more detailed information).

### History of the distribution of agricultural genetic diversity

Most crops were first domesticated during the Neolithic period. The early expansion of agriculture may be considered the first phase in the distribution of agricultural genetic diversity. Later, trade routes between the Arabian peninsula, East Africa, Europe and Asia were extremely important in the movement of crop genetic diversity between regions.

## Regions of diversity of major cultivated plants[32]

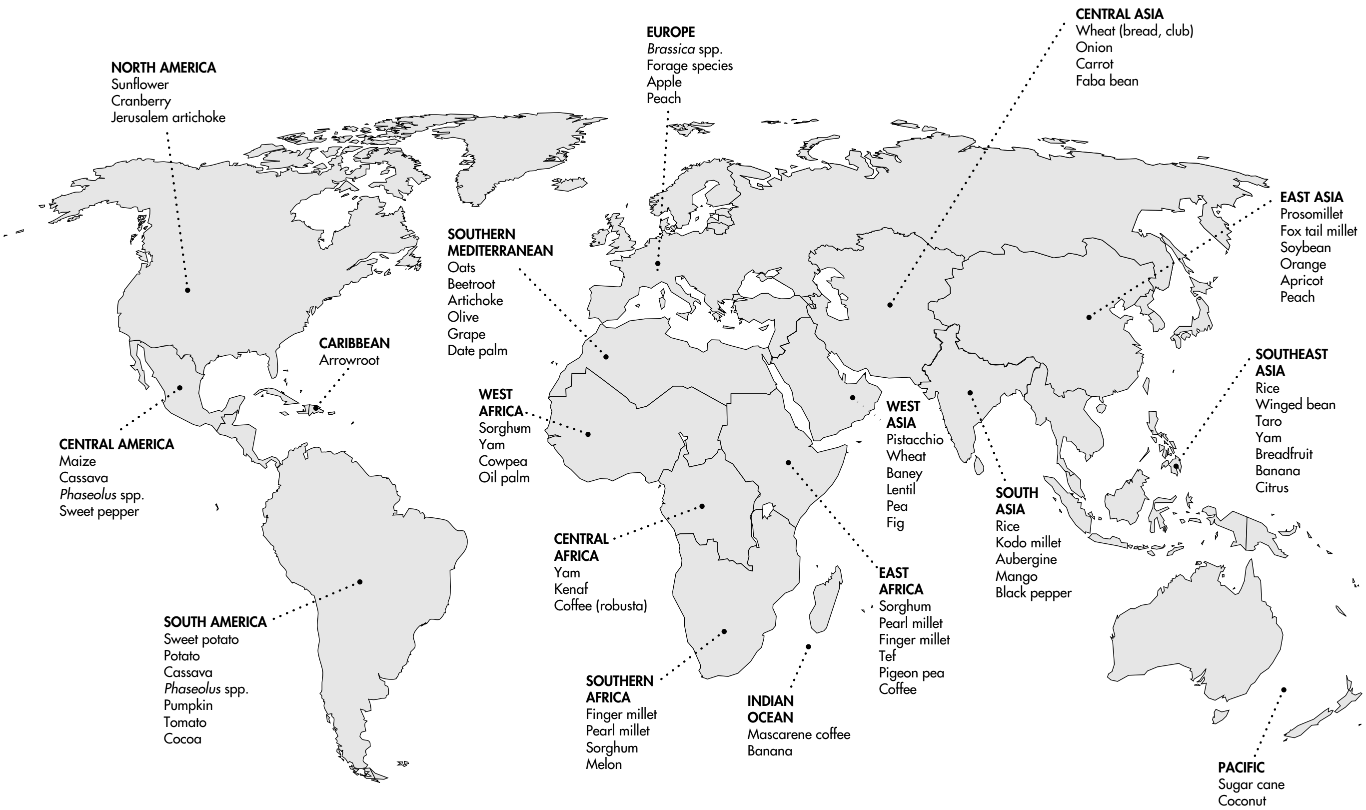



Figure 1.4

The second phase was brought about by the advent of maritime exploration, especially the opening of communication between the old and new worlds after 1492. Links between Europe, Africa, the East Indies and later the Pacific, led to an increase in the worldwide exchange of PGRFA and an intense interest in exotic plant collecting generally.[30] Voyages of exploration opened the way for widespread collecting and the beginning of *ex situ* conservation of plants, particularly in botanical gardens.

This exchange also led to the marginalization of many traditional crops when these were replaced by introduced ones. In some areas more crop diversity existed historically than is generally acknowledged. A number of crops domesticated in North, South and Central America, for example, were lost with the demise of indigenous societies.[31]

In more recent times, large and comprehensive collections of crop genetic resources have been collected and conserved, notably in international centres and other large genebanks (see Chapter Three). The result is that large amounts of the genetic diversity of some major crops can be found in *ex situ* collections.

## Secondary centres of diversity

The history of the exchange of genetic resources has led to the development of important secondary centres of diversity for some crop species. For example, significant diversity in varieties of the common bean, maize and cassava has evolved and been developed by farmers in African countries since these species were introduced from Latin America. Similarly, finger millet developed important characteristics in South Asia after its introduction from East Africa several thousand years ago. Now, South Asia is an important source of finger millet diversity.[33] Barley, which originated as a crop in the Fertile Crescent of the Near East, developed important disease resistance qualities in Ethiopia after its introduction there some 5,000 years ago.

Crops such as rye and oats from the Near East and Mediterranean may have been introduced as weeds in northern European barley and wheat fields, where they were domesticated and developed during ancient times. The hybrid maize industry still relies heavily on materials developed by farmers in the United States in the 1800s and early 1900s. There is a need for more information about the diversity of such secondary centres. It should be noted that the history of the exchange of genetic resources has evolved in such a way that a country providing a sample of genetic material (the country of origin in the legal sense as defined by the Convention on Biological Diversity[34]) will rarely be the only country able to provide such a sample. This country will also not necessarily coincide with the country of origin in the historical or evolutionary sense.

## Interdependence for PGRFA

Today, the agriculture of virtually all countries is heavily dependent on a supply of resources from other parts of the world. For instance, according to one study, North America is completely dependent upon species originating in other regions of the world for its major food and industrial crops, while sub-Saharan Africa is estimated to be 87% dependent on other parts of the world for the plant genetic resources it needs[35] (Figure 1.5). Furthermore, over two-thirds of developing countries acquire more than half of their crop production from crops domesticated in other regions.[36] Even though many countries hold a significant amount of plant genetic diversity for food and agriculture in their genebanks and farmers' fields, in the long term, they are likely to require access to additional diversity from the crop species' centres of diversity. The need for exchange of plant genetic resources is not likely to subside.

Crops such as cassava, maize, groundnut and beans, which originated in Latin America but have become staple food crops in many countries in sub-Saharan Africa, demonstrate the interdependence of crop species between developing

**Percentages of food production of major crops based on species originating from other regions**

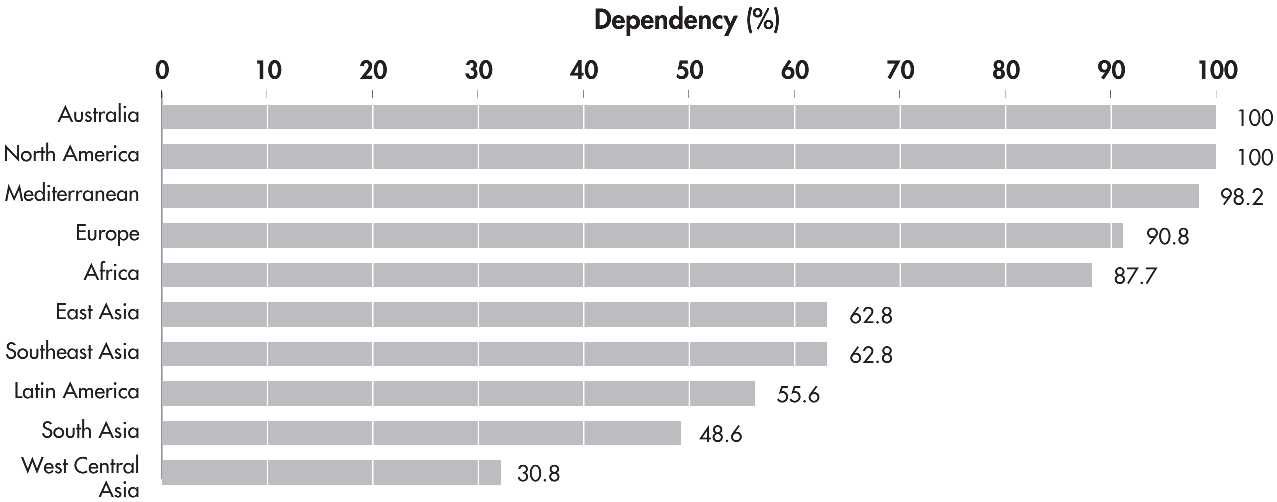



Figure 1.5

*Source:* adapted from Kloppenburg & Kleinmann (1987)

countries. Cassava is a major food item for 200 million Africans in 31 countries[37] with a farmgate value of over US ò7,000 million .[38] On the other hand, Africa — with its indigenous millets and sorghums — makes a considerable contribution to other areas such as South Asia (13%) and Latin America (8%).[39] Developing countries in Asia have a higher annual production of crops indigenous to the Latin America region — cassava, maize and rubber (valued at ò27,000 million) — than do the Latin American countries themselves, where annual production of crops originating in the region is valued at ò14,000 million.[40]

Some countries, though rich in biological diversity, are still heavily dependent upon genetic resources originating in other parts of the world. In Brazil, for example, almost half of the population's energy from plant sources comes from three major cereals - rice, wheat and maize - all of which originated in other parts of the world. Sugar (cane), which supplies one-fifth of energy intake, originated in Southeast Asia. Of major food sources, only cassava, which supplies about 7% of energy intake, originated in Brazil.

# 1.4 THE VALUE OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

## 1.4.1 The types of value of genetic resources and genetic diversity

When considering the value of plant genetic resources, not only the conservation of particular genes and genotypes but also the conservation of variability or diversity per se need to be taken into account. The latter refers to the maintenance of a wide range of species, varieties, gene complexes and genes, rather than of any one particular gene or genotype.

### The value of genes and genotypes

Genes or genetic characteristics are valued for the benefit they provide, including such agronomic qualities as resistance to pests, diseases and drought; adaptations to abiotic stresses such as salinity tolerance; plant stature and other factors affecting productivity; quality factors such as higher oil or protein content; as well as culinary and other factors of cultural importance. These characteristics, which are important to farmers (see Section 1.4.2), are also of major global significance as they are introduced into many modern varieties (see Section 1.4.3). As described below, particular genotypes are also especially important to farmers in resource-poor areas, as they tend to be well adapted to local conditions. The particular combination of genes in a well-adapted landrace, for example, may be difficult or impossible to reconstruct.

### The values of genetic variability

Three values - portfolio value option value and exploration value - can be distinguished in relation to the three functions of genetic variability:

- Genetic diversity helps to provide stability (portfolio value) for farming systems at the local, national and global levels by smoothening yield variability through the maintenance of a wide range, or portfolio, of crops and intracrop diversity. Losses due to the failure of a particular crop or variety are compensated for by the yield of other crops or varieties.
- Genetic diversity provides insurance (option value) against future adverse conditions as needs are constantly changing and because genetic resources may later prove to provide useful characteristics, such as resistance to new diseases or adaptability to changed climatic conditions.

- Genetic diversity represents a "treasure chest" of potentially valuable but as yet unknown resources (exploration value). This is the reason for maintaining both wild ecosystems and traditional farming systems, as plants in these habitats are likely to contain and develop new and valuable genetic characteristics.

### 1.4.2 The value of genetic diversity to small farmers

Farmers who can afford to invest in appropriate improved crop varieties and external inputs are usually rewarded with increased yield and income. Many farmers in developing countries (see Box 1.1) cannot afford expensive external inputs such as fertilizers, pesticides or seeds adapted and improved for the particular ecological and economic situation. Plant genetic diversity, both at intra- and interspecific levels, is therefore a crucially important part of their farming systems. This point was emphasized by many countries during the preparatory process for the International Technical Conference.[41]

#### Box 1.1 Who are the world's farmers?

Resource-poor farmers constitute over half of the world's farmers and produce 15-20% of the world's food.[42] These farmers have not benefited as much as others from modern high-yielding varieties.[43] It is estimated that some 1,400 million people, approximately 100 million in Latin America, 300 million in Africa and 1,000 million in Asia[44],are now dependent on resource-poor farming systems in marginal environments.[45]

A majority of the world's resource-poor farmers are women. Worldwide, women produce more than 50% of all the food that is grown.[46] In many developing countries, this percentage can be much higher. For instance, it is estimated that women produce 80% of the food grown in sub-Saharan Africa, 50-60% in Asia, 46% in the Caribbean, 31% in North Africa and the Near East, and about 30% in Latin America.[47]

Furthermore, while improved varieties will usually have a higher potential yield than traditional varieties, such yield potential often cannot be achieved in resource-poor environments and may involve risks to people's livelihoods. As noted above, by using locally adapted farmers' varieties, or mixtures of varieties, farmers are able to spread the risk of crop failure resulting from pest and disease epidemics or adverse environmental effects such as drought.

Often, farmers' varieties are well adapted to poor conditions. The countries of West Africa report, for example, local varieties of fonio which grow in low-fertility soils in arid zones.[48] Similarly, southern African countries note that in the difficult and unpredictable growing conditions that characterize much of the region (poor or erratic rainfall, very long or short growing seasons, no external inputs), it is landraces which provide smallholder farmers with a more reliable crop yield. In China, local varieties are valued, especially in the remote mountain areas where they are adapted to diverse ecosystems, including cold climate, dry and flooded areas, and saline, alkaline and acid soils.[49]

In highly variable environments, higher total household production may be obtained from employing a range of crop varieties, each specifically adapted to the micro-environment in which it grows. Farmers also often use intercropping and agroforestry techniques that employ mixtures of species with complementary requirements, such as cereals with pulses. Intercropping is the norm for maize, millet, cowpea and many bean varieties in small farming systems. In some cases, crop varieties have become adapted to each other as a result of intercropping.[50]

Farming systems based on diversity also provide a range of products with multiple uses, including varied food and other products, fuel, medicines, construction material, etc. The use of a wide diversity of crops and crop varieties can also be very important from a nutritional perspective. Traditional vegetables, often grown in gardens, provide valuable minerals, vitamins and amino acids, making a substantial contribution to household food security. The contribution of such plants to alleviating micronutrient deficiencies is greatly underappreciated. In addition, complex farming systems based on diversity tend to support a wider range of animal and fish life which also make a valuable contribution to local diets.

Women farmers are particularly aware of the usefulness of plant genetic diversity as in many parts of the world they are the ones with primary responsibility for the production of subsistence crops that are essential to household food security.[51] Women are often a reservoir of traditional knowledge of cultivation, maintenance and use of traditional varieties.

Plants growing among the main crop, in a weed-like manner, may also be harvested and used as an important food source. For example, in Kenya, women collect traditional vegetables growing within maize crops. These are an important source of protein, vitamins and minerals which supplement the maize-based diet.[52] Also, in West Africa, certain weedy forms of *Gossypium* are of nutritional and therapeutic value. For example, the seeds are used as a source of protein for the under-nourished and to treat certain illnesses.[53] A range of diversity can also be important for the local economy. In West Africa, bambara groundnut and fonio are sold in the markets at times when the major food crops are unavailable.[54]

The complex use of diversity in farming systems is further illustrated by bean production in Malawi by small-scale farmers.[55] Farmers in Malawi typically grow a large number of varieties (an average of 12 seed types[56]), some in pure stands, some in mixtures and some interplanted with local or hybrid maize. Some are planted during the main growing season, others during the off-season. Each is valued for different reasons. Farmers attach high importance not only to yield, but also to various other attributes including taste, cooking ability, marketability, early maturity, ability to utilize residual soil moisture, and storability.

Although multcropping is recognized as a common feature of many small-scale farms in developing countries, it is notable that in many developed countries there is growing demand for a wider choice and variety of horticultural crops where, increasingly, diversity in taste, colour, nutritional value and earliness/lateness are highly valued in the marketplace.[57]

### 1.4.3 The value of plant genetic resources for food and agriculture in modern varieties

The improvements in agricultural production brought about through the use of modern varieties have been possible because of the rich and varied genetic diversity in farmers' landraces, together with material from wild and weedy species.

The initial stages of breeding for most crops have been based on locally adapted landraces. For instance, the wheat variety "Marquis", which was grown across 90% of the spring wheat area of the North American Great Plains originated from a cross between the Indian landrace 'Hard Red Calcutta' and the European landrace "Red Fife".[58] Similarly, the breeding of winter wheat in Europe is historically based on a large pool of selections derived from numerous wheat landraces from many countries.[59]

It has been estimated that 11 landraces contributed to the commercial malting barley genepool,[60] while the prominent commercial alfalfa ecotype, AWPX3, is known to have originated from 13 ecotypes collected in nine countries.[61] The development of improved breeding lines for many crops which are in the early stages of formal plant breeding (e.g. amaranth, *Chenopodium* spp. and teff) also relies heavily on the use of landraces.[62]

Landraces have provided many individual traits which have been introduced into existing improved breeding lines. Some examples of the introgression of useful traits from landraces into existing cultivars are given in Box 1.2. It should be noted that some genes which once appeared to be of no particular value have since proved crucial in developing new varieties and conferring various resistances. Annex 1-3 provides information about techniques used. The International Centre for Maize and Wheat Improvement (CIMMYT) records a steady increase over time in the average number of landraces in the genealogies of its wheat varieties (12 in 1950, 64 in 1992).[63]

**Box 1.2 Examples of the introgression of valuable agronomic traits from landraces**

- One Turkish wheat landrace was found to carry genes for resistance and tolerance to various rusts, smuts and other fungal pathogens. It was used as a source of resistance genes and is a parent of many of the wheat cultivars now grown in the northwestern United States.[64]
- A dwarf wheat landrace from Japan, Daruma/Norin 10, which was introduced into the United States in 1946, was used as a donor of dwarfing genes which increased production by increasing nitrogen uptake.[65]
- Zerazera sorghums from Ethiopia have provided resistance to downy mildew in many inbred lines widely used in the United States and Mexico.
- Italian ryegrass (*Lolium multiflorum*) landraces, collected in Uruguay in the 1950s, were the source of resistance to crown rust.
- A local landrace of brome grass (*Bromus biebersteinii*), collected in Turkey in 1949, is responsible for the optimum vigour and agricultural characteristics of the famous Regar variety produced in the United States.
- One alfalfa landrace collected in Iran in 1940 was used to introduce resistance to stem nematodes.[66]

Wild relatives can also make enormously useful contributions to plant improvement. They have evolved over a long period of time and have coevolved with pests and diseases.[67] One particularly outstanding example is that of the tomato (*Lycopersicon esculentum*). Wild species have been used as donors of genes for fungus resistance (*L. hirsutum*, *L. pimpinellifolium*); virus resistance (*L. chilense*, *L. peruvianum*); nematode resistance (*L. peruvianum*); insect resistance (*L. hirsutum*); fruit quality (*L. chmielewskii*); and adaptation to adverse environments (*L. cheesmanii*).[68] Additional examples are given in Box 1.3 .

**Box 1.3 Examples of introgression of valuable agronomic traits from wild relatives of crops**

- Resistance in cultivated potato (*Solanum tuberosum*) against cyst nematodes has been introduced from the wild relative *Solanum demissum*.[69]
- Stem rust resistance in cultivated wheat (*Triticum aestivum*) has been introduced from the wild relative *Triticum timpheevi* and from *Agropyron* spp.[70]
- Resistance in cultivated rice to grassy stunt virus of rice, *Oryza sativa*, has been introduced from the wild rice, *Oryza nivara*,[71] and resistance to brown planthopper by *Oryza officinalis*.
- Some wheat varieties are protected from eyespot fungus by resistance genes from the wild grass, *Aegilops ventricosa*.[72]
- In Africa and India, cassava yields have been increased up to 18-fold with the disease resistance provided by genes from wild Brazilian cassava.[73]
- In Mediterranean rainfed areas, genes from the wheat wild relative *Triticum polonicum* contributed low fertilizer input qualities to the durum wheat cultivar Sebou.[74]
- A wild relative of sorghum, *Sorghum virgatum*, has provided the source of resistance to greenbugs in cultivated varieties.[75]

The green revolution of the 1960s permitted spectacular increases in yields of rice and wheat, without which it is unlikely that the food needs of rapidly expanding populations would have been met. In wheat, rice and maize, about half of the increase in production has been ascribed to breeding new varieties through the use of plant genetic resources, the remainder deriving from the use of fertilizers, pesticides, fungicides and improved crop management.[76] Over the past 25 years, irrigated rice production has increased at 3% per year. Nearly 60% of this growth is the result of increases in yield from breeding.[77] Between 1930 and 1990, yields of maize and sorghum have increased between four- and fivefold in some areas. (Annex 2 provides examples of yield increases for a range of crops globally and in selected sub-regions.)

## 1.4.4 Indicators of the monetary value of PGRFA to food and agricultural production

There is no doubt that plant genetic resources are valuable. For example, the transfer of genes conferring high sugar content to cultivated tomato (*Lycopersicon esculentum*) from the wild relative (*L. chmielewskii*) is estimated to be worth US ò5 to ò8 million per year to the tomato industry.[78] Estimates of the global value associated with the use of plant genetic resources for food and agriculture vary from hundreds of millions to tens of billions of dollars per year. For example, the contribution of rice landraces from South Asia, assembled in the region's genebanks, is estimated to be about ò150 to ò200 million per year.[79] Several estimates have been made of the value of CIMMYT-based wheat germplasm to agriculture in OECD countries. These range from ò300 million to ò11,000 million per year;[80] the differences reveal the difficulty in assessing monetary value. Furthermore, most estimates do not give the value of the genetic material per se, but rather the aggregate value of both the genetic material and the work of plant breeders and other research inputs. This is discussed further in Chapter Seven. Some methods of estimating the value of genetic resources, or the value associated with the use of genetic resources, are given in Annex 1-4.

The estimated annual turnover of the commercial seed industry in OECD countries is ò13 billion. Extrapolated from this, it has been estimated that the total seed sector including parastatal and informal activities is worth about ò45 billion.[81] (see Chapter Four for more on seed sales). In this context, it should be noted that the commercial value of PGRFA, as represented by revenues from seed sales, is much less than that generated by the sale of pharmaceuticals.[82]

## 1.5 GENETIC VULNERABILITY AND GENETIC EROSION

### 1.5.1 Genetic vulnerability

Genetic vulnerability is 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.[83]

One of the main causes of genetic vulnerability is the widespread replacement of genetically diverse traditional or farmers' varieties by homogeneous modern varieties.

In assessing the degree of potential vulnerability, two factors are of concern: (i) the relative areas devoted to each cultivar, and (ii) the degree of uniformity (relatedness) between cultivars.

The extent of uniformity is not always apparent because pedigrees are not always available, even for the most popular cultivars. Although plant breeders' rights legislation in some countries requires that pedigrees be submitted, in others they are protected as "confidential". In addition, data on areas sown to different cultivars of the same crop are not usually available.

There are a number of means by which the genetic vulnerability of crop production can be assessed (see Annex 1-1). While such assessments are rare, it is known that many of today's widely planted modern varieties of food crops are impressively uniform genetically and impressively valuable.

In the Netherlands, for example, the three top varieties of nine major crops covered from 81 to 99% of the respective areas planted. One cultivar accounted for 94% of the spring barley planted.[84] In 1982, the rice variety "IR36" was grown on 11 million hectares in Asia.[85] Over 67% of the wheat fields in Bangladesh were planted to a single wheat cultivar ("Sonalika") in 1983, and 30% of Indian wheat fields to the same cultivar in 1984.[86] Reports from the United States in 1972 and 1991 indicate that for each of eight major crops fewer than nine varieties made up between 50% and 75% of the total.[87] Ireland's Country Report cites 90% of its total wheat area sown to just six varieties.

The accumulated anecdotal evidence from various sources suggests that there are large areas planted to a small number of varieties and although in some major wheat-producing areas the situation is improving, it is still worthy of concern. It should be noted that reduction of diversity of farm varieties began to occur even before the advent of semidwarf wheats, and is associated with the commercialization of agriculture.[88]

Even where cultivars have different names, the degree of genetic difference between them may be slight. In European barley, for example, protection against mildew is increasingly dependent on one gene and one fungicide.[89] Mutation of the pathogen could wipe out this resistance in a single evolutionary step.

There are also numerous cases where most, or nearly all, cultivars share the same genetic trait. All F1-hybrids of rice - covering 15 million hectares in China (1990) - share the same genes for male sterility. The same applies to sunflowers. Furthermore, all modern rice varieties share the same dwarfing gene.[90]

Uniformity per se need not be dangerous, for some crop cultivars are remarkably stable.[91] However, the dangers of planting large areas to a genetically uniform crop variety must be recognized, as these varieties could suddenly become uniformly susceptible to new pathogen races and be wiped out. The most famous example of this is the potato famine of 1845-1848, when a pandemic of late blight (*Phytophthera infestans*) wiped out the potato crop in Europe and North America. In Ireland alone this led to the deaths of 1.5 million people who were wholly dependent on potatoes for their staple diet and did not have the economic or political means to avert catastrophe. The potatoes grown in Europe at that time were genetically uniform, as they were based on the two to four original varieties introduced into Europe from South America. The threat of further disease epidemics in potatoes still exists. In the 1980s there was an outbreak of a new race (A2) of late blight which again hit Europe, Asia and Latin America.[92] In 1992, a new sexually reproducing race of late blight was detected in Mexico which was resistant to all known disease-resistance genes and fungicides. This rapidly mutating race has since been detected in North America.[93] Some further examples of vulnerability are outlined below:

- The genetic uniformity of resistance genes in modern wheat varieties in India was responsible for many severe epidemics of Shoot fly (*Atherigona* spp.) and Karnal bunt (*Tilletia indica*) in the 1970s.[94]
- In 1970, a new race of maize leaf blight destroyed more than 15% of the United States maize crop as a result of the same cytoplasmic genes being used in the breeding of all the major varieties. Drawing from this experience, in 1972 the United States National Research Council recommended that the genetic base of the major crops be diversified.[95]
- In 1975, the United Kingdom list of recommended varieties of white clover (*Trifolium repens*) had to be totally abandoned for several years when a new pathogen, *Sclerotinia trifoliorum*, killed off white clover populations throughout much of the United Kingdom. All recommended varieties were susceptible.[96]
- In 1972, the winter wheat cultivar "Bezostaya"was grown over 15 million hectares in the Soviet Union. It had been moved beyond its original area of cultivation far into the Ukraine during a succession of mild winters. However it was wiped out in 1972 by a severe winter.[97]
- In Cuba, during 1979/80, a rust attack on the variety of sugar cane which covered 40% of the country resulted in the loss of more than 1 million tonnes of sugar, worth about US ò500 million.

Bananas are another example of the costs of genetic uniformity. All five major varieties used for commercial production derive from one original banana variety (Cavendish). All these varieties are highly susceptible to the fungal disease black Sigatoka which can only be controlled by regular chemical applications.

The cost of controlling the disease is high, surpassing ò350 million in fewer than eight years in Central America, Colombia and Mexico. Moreover, small landowners cannot control the disease in their fields as they lack both the equipment and the funds required for fungicide applications. Yield losses approaching 47% have been reported in Honduras and other Central American countries. The disease is also causing major losses to plantain producers in West Africa.[98]

Crop insurance schemes and other forms of livelihood maintenance are another indication of the costs associated with genetic vulnerability. Such schemes are a well-established means of protection against crop losses in many developed countries, and, increasingly, in many developing countries as well.

Different governments provide public insurance systems or subsidize private insurance companies. For instance, the United States Government in the 1980s spent ò3.8 billion on subsidizing private sector multi-peril crop insurance.[99] A number of other countries (India, the Philippines, Cyprus and Venezuela) have insurance schemes which include cover against losses due to pests and diseases.[100]

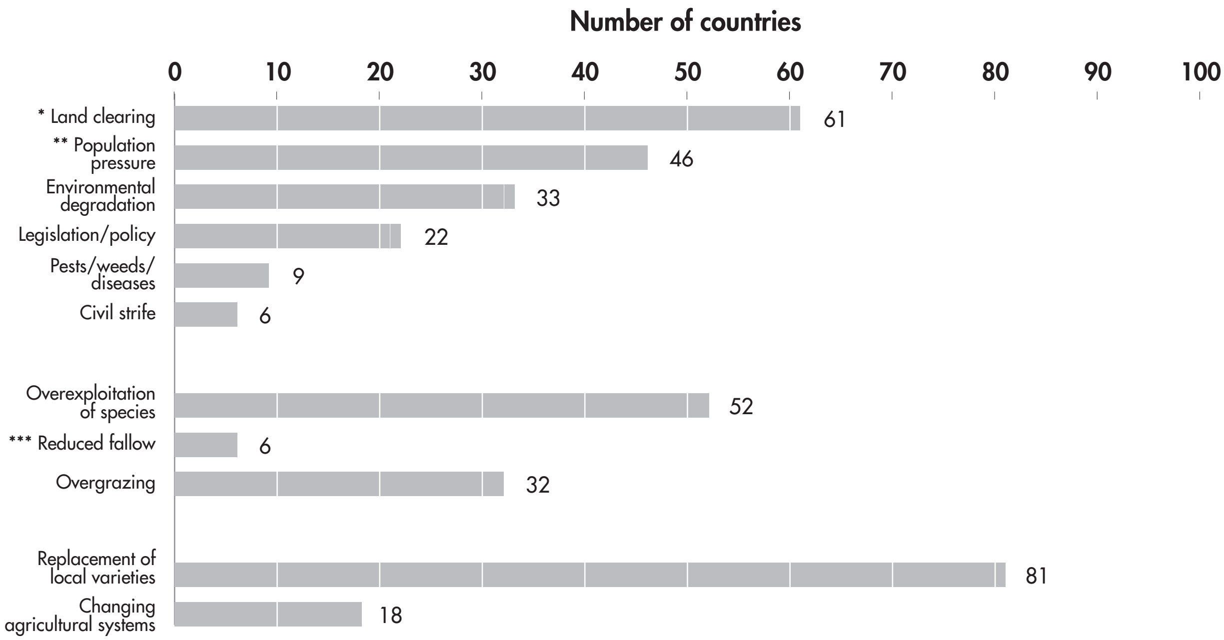
For many resource-poor farmers who cannot pay insurance premiums the only option is to minimize risk through the use of inter- and intra-specific crop diversity. The degree to which crop diversification or different types of cultivars are able to increase stress resilience and thus replace the need for insurance systems is not yet well known and further research is required. Public funding for such research, however, competes with government subsidization of crop insurance.[101]

### 1.5.2 Genetic erosion

Genetic erosion is the loss of genetic diversity, including the loss of individual genes,[102] and the loss of particular combinations of genes (i.e. of gene-complexes) such as those manifested in locally adapted landraces. The term "genetic erosion" is sometimes used in a narrow sense, i.e. the loss of genes or alleles, as well as more broadly, referring to the loss of varieties.

The main cause of genetic erosion in crops, as reported by almost all countries, is the replacement of local varieties by improved or exotic varieties and species. As old varieties in farmers' fields are replaced by newer ones, genetic erosion frequently occurs because the genes and gene complexes found in the diverse farmers' varieties are not contained *in toto* in the modern variety. In addition, the sheer number of varieties is often reduced when commercial varieties are introduced into traditional farming systems. While some indicators of genetic erosion have been developed (see Annex 1-1), there have been few systematic studies of the genetic erosion of crop genetic diversity which have provided quantifiable estimates of the actual rates of genotypic or allelic extinction in PGRFA. Nearly all countries, however, in their Country Reports, say that genetic erosion is taking place and that it is a serious problem. The main causes of genetic erosion, as indicated in the Country Reports, are shown in Figure 1.6.

**Causes of genetic erosion mentioned in Country Reports**




* Including deforestation and bush fires
** Including urbanization
*** Reported in the case of shifting cultivations

Figure 1.6 *Source:* Country Reports

## Variety replacement

The replacement of local varieties or landraces by improved and/or exotic varieties and species is reported to be the major cause of genetic erosion around the world. It is also cited as the major cause of genetic erosion in all regions except Africa. Examples are mentioned in 81 Country Reports, of which a number are highlighted below.

- A survey of farm households in the Republic of Korea showed that of 14 crops cultivated in home gardens, an average of only 26% of the landraces cultivated there in 1985 were still present in 1993. The retention rate did not exceed 50% for any crop, and for two crops it was zero. These results are disturbing as such home gardens have traditionally been important conservation sites, especially for vegetable crops.[103]
- In China, in 1949, nearly 10,000 wheat varieties were used in production. By the 1970s, only about 1,000 varieties remained in use. Statistics from the 1950s show that local varieties accounted for 81% of production, locally produced improved varieties made up 15% and introduced varieties 4%. By the 1970s, these figures had changed drastically; locally produced improved varieties accounted for 91% of production, introduced varieties 4% and local varieties only 5%.[104]

- In Malaysia, the Philippines and Thailand, it is reported that local fruit varieties are gradually being replaced with better quality varieties, such as guava in Malaysia and rambutan in the Philippines. The same phenomenon is taking place in all three countries with rice and maize.[105]
- In Ethiopia, traditional barley and durum wheat varieties are suffering serious genetic erosion due to displacement by introduced varieties.[106]
- Genetic erosion is particularly noticeable in Eastern European countries (with the exception of Poland).[107] In the Federal Republic of Yugoslavia (Serbia and Montenegro), for example, it was estimated that the area sown with old varieties of wheat is now less than 0.5%.[108]
- The large-scale genetic erosion of local varieties of native Andean crops, such as *Ullucus tuberosus, Oxalis tuberosa, Tropaeolum, Polymnia sonchifolia, Mirabilis expansa* and *Pachyrhizus tuberosus,* is reported in the Country Report of Ecuador. Argentina reported the genetic erosion of *Amaranthus* and quinoa.[109]
- The Country Report of Uruguay stated that many landraces of vegetables and wheat have now been replaced by modern varieties, and in Costa Rica genetic erosion is reported within the native gene pools of cultivated maize and *Phaseolus vulgaris,* due to landrace replacement by modern varieties.
- Chile reported genetic erosion of local potato varieties as well as other crops such as oats, barley, lentils, watermelon, tomato and wheat.
- Genetic erosion of maize in Mexico is well documented with baseline data provided by an inventory taken in the 1930s. A comparison with current data shows that only 20% of the local varieties reported in 1930 are now known in Mexico due to decreases in the area of land planted with maize and the replacement of maize with other more profitable crops.

One study providing a historical perspective on the loss of crop varieties was based on United States Department of Agriculture (USDA) information about varieties being grown by farmers in the United States during 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 United States 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. The loss of such large percentages of cultivars probably indicates some loss of genetic diversity. However, it should be noted that loss of cultivars and loss of diversity are not synonymous. Genes in a lost cultivar may still exist in other currently available cultivars.[110]

### Other agricultural changes

The intensification of agricultural systems often results in habitat destruction. Hedgerows are cleared, swamps are drained, large-scale irrigation is introduced and agricultural chemicals, particularly herbicides, are used. Changes in agricultural systems are reported as causes of genetic erosion by some 18 countries. Several specific examples of habitat destruction were reported, including dam construction in the United Republic of Tanzania, swamp drainage and large-scale irrigation in Belarus and land drainage in France.[111]

Such changes can have particular effects on wild crop relatives. For example, China reports a great reduction in the populations of wild groundnut in the Yellow River Islet, and of wild rice in Yunnan Province.[112] Mexico reports widespread genetic erosion of wild populations of *Zea* spp.

### Lack of sustainable resource management

Overexploitation of plant genetic resources, including overgrazing and reduced fallow periods in shifting cultivation, are examples of poor resource management which are cited in 67 Country Reports.

Excessive harvesting of wild of plants for food, medicine and the ornamental flower trade is another important cause of genetic erosion. This is particularly noticeable in parts of Africa and is reported in, among others, Madagascar and Comoros .[113] Panama also reports widespread genetic erosion of forest species due to over exploitation.

Overgrazing is reported as a cause of genetic erosion by 32 countries. It is particularly important in the Near East, where it is reported by 60% of countries, and it is also a common factor in genetic erosion in parts of Southern Africa. In Uruguay, there has been genetic erosion of the gene pool of the native fodder grasses due to overgrazing and reforestation policies.

Reduced fallow periods in shifting cultivation are identified as a cause of genetic erosion in Mozambique, Sierra Leone and the United Republic of Tanzania.

### Deforestation and land clearance

In Africa, the most frequently cited cause of genetic erosion, as mentioned by 74% of the countries reporting from this region, is the destruction of forest and bush lands. This includes the clearance of land for agricultural crops, the collection of fuelwood and the burning of forest and bush land to provide pasture land. Such land clearance is also an important cause of genetic erosion in other parts of the world, more particularly in areas of South America, and in South and Southeast Asia.[114]

Most countries in Latin America reported major genetic erosion of economically important forest species. In Colombia, it is estimated that between 300,000 and 800,000 hectares of forest are cleared every year, and that many forest plant species of economic importance are now endangered. Ecuador has the highest rate of deforestation in South America, and the result is very intensive genetic erosion of forest plant species. Wild species such as *Dicliptera dodsonii* and *Tabebuia chrysantha* are now on the verge of extinction and populations of *Miconia* and *Scalesia* spp. have vanished from many areas of the Galapagos. In Peru, the genetic erosion of ten forest species is reported from the jungle, the sierra and the coast.

### Environmental effects

Many species in desert zones are not only threatened by overcutting and overgrazing, but are also subject to recurrent droughts which can lead to desertification. Such effects are reported by, among others, Cameroon, Burkina Faso, Guinea, Kenya, Morocco, Nigeria, Senegal, Saudi Arabia and Yemen.[115] Other adverse environmental conditions, such as flooding in Bangladesh and cyclones in the Pacific, may also cause genetic erosion.[116]

The adverse impact of pollution on genetic diversity is reported by 33 countries. Genetic erosion caused by acid rain, for example, is reported by many European countries and the Republic of Korea.[117]

### Introduction of new pests and diseases

The inadvertent introduction of new pests and diseases is cited as a cause of genetic erosion by a number of countries, particularly small island developing states.[118] For example, in several Pacific states the main threat to landraces of taro is the occurrence of taro leaf blight.[119] In the Maldives, *Citrus* has been nearly wiped out through new bacterial diseases and the recent introduction of white flies has nearly killed most of the guava plants,[120] while Mauritius reports that many introduced exotic plants which have become naturalized — Chinese guava, privet and poivre marron — have displaced native forest plants as a result of intense competition, and that the regeneration of native species is compromised by rats, monkeys and birds. Similar problems are reported by the Seychelles.

### Population pressure, urbanization and other factors

The impact of increasing population pressure and the resulting urbanization of environments frequently have a negative impact on plant genetic diversity. This process is reported by 46 countries around the world, and is particularly notable in parts of South Asia and the Near East. Land development for tourism can also cause genetic erosion, as reported by Swaziland, Mexico, Chile and Greece.[121]

Widescale changes in the cultural and ethnic composition of societies can also be an indicator of the status of genetic diversity and traditional crop varieties. The disappearance of many languages in this century, and the threatened status of perhaps half of the world's remaining 6,500 languages, may be one specific indicator, as the relationship between cultural and genetic diversity is well documented.

### War and civil strife

In some countries, war and civil strife have contributed significantly to genetic erosion. In Rwanda and Somalia, they have resulted in the neglect of fields and the consumption of seed, while in Angola and Cambodia, they contributed to the loss of many traditional varieties as people moved from one area to another in search of safety. Farmers were unable to preserve their local varieties. In Viet Nam, genetic erosion was one of the consequences of the large-scale use of defoliants during the war in that country.[122]

### Policy and legislation

Government policy can also have an impact on the extent of genetic erosion. In Europe, current legislation discouraging the cultivation of farm landraces has had a strong negative impact on conservation. In Africa, the replacement of traditional agricultural practices by modern practices is common, as is policy support of high-yielding varieties to boost agricultural production.[123]

### Economic processes and genetic erosion

Genetic erosion is also the result of economic pressures. In spite of the value and importance of maintaining genetic resources, including a large number of traditional crops, the individual farmer rarely realizes this value in the form of direct financial benefit. In economic terms, this is called "a failure of appropriation". Such failure of appropriation is common in the case of public goods.[124] The farmer has little financial incentive to continue growing these crops. There is, in fact, a disincentive when higher income can be had by converting from traditional varieties

### Box 1.4 The economics of genetic resources loss[125]

The conversion of land to more specialized forms of production is one of the main causes of the loss of biodiversity, including plant genetic diversity within agricultural production systems. Conversion means substituting a large number of genetically heterogeneous local varieties, or landraces, with a small number of modern, genetically uniform varieties which are more profitable to farmers. Other economic processes that are speeding up such conversions are specialization and globalization. Specialization results from the inertia that develops around particular assets, in this case species or varieties. Once capital is invested in specialized plant breeding and farming systems, globalization results from the economies of scale applied to such capital goods as pesticides or agricultural machinery in specialized production systems. Under such conditions, it may be cheaper, for example, to select chemicals that are suitable for a few crops, varieties and environments and mass produce these, rather than to produce a range of products for a range of needs.

Three values of genetic diversity have been identified: the portfolio, option and exploration values. As described earlier, farmers can derive benefits from the portfolio value at the local level. In subsistence agricultural systems, farmers balance considerations of yield maximization and yield stability in selecting their individual optimal crop portfolios (sometimes growing both landraces and modern varieties). This value, however, usually diminishes with economic development, because farmers need to rely less on crop diversity as they begin to be able to offset the effects of crop failure by selling labour (particularly in urban areas) or drawing upon accumulated assets. In addition, farmers do not benefit from the other values of genetic diversity.

What farmers do see is the cost of maintaining diversity, which is the 'opportunity cost' or potential income lost by not planting modern varieties. When the farmer's cost surpasses the local portfolio value, there is an incentive to convert to modern agriculture. Similar factors work at the national level. While governments may appreciate the local and national portfolio values, they have difficulty appropriating them in any meaningful way and cannot appropriate the global portfolio value at all. Smaller and poorer states, in particular, see few incentives in conserving a high level of diversity, because they appropriate only a small proportion of the benefit. Their farmers are encouraged to switch to high-yielding varieties, rather than maintain diversity.

Plant breeders and seed companies appropriate the exploration value when they market varieties that have incorporated farmers' material. This value however, does not return to the farmers' from whom the germplasm came. If this value could be appropriated by the farmers and their communities and countries, substantial areas with diverse agro-biodiversity would have a much better chance of being preserved. Without greater incentives to maintain such biodiversity, greater than the opportunity cost of not converting, there is no real prospect for change in the immediate future, and states with rich genetic resources in traditional agriculture will see little reason for retaining this diversity.

The major factor driving genetic erosion is that traditional farmers who develop and conserve agro-biodiversity, are generating a "public good", without adequate incentives. They are producing global values for which they obtain no return. Without appropriate and urgent solutions to this paradox, the loss of agro-biodiversity will accelerate, and the consequences will be serious, irreversible and global.

to modern varieties. Without taking steps to make it worthwhile for an adequate number of farmers to continue to grow and develop such crops, economic forces will lead to continued genetic erosion (see Box 1.4).

## 1.6 ASSESSMENT OF MAJOR NEEDS — AN INTEGRATED APPROACH TO THE CONSERVATION AND UTILIZATION OF PGRFA

### Diversity and food security - major crops, minor crops and underutilized species

World food security depends, to a large extent, on the 30 crop species that provide most of the dietary energy or protein and, in particular on the three crops - rice, wheat and maize - which together provide more than half. Other major crops, such as cassava, sorghum and millet, are also essential to food security, particularly for resource-poor people. Genetic diversity within all these species is important for their continued stable production.

When food supplies are assessed on a country by country basis there are about 100 crops that are important for food security. However, a much larger number of minor crops and underutilized species are important at the local level.

With respect to the major crops, the following needs can be identified to promote food security:

- the need to reduce genetic erosion in the field (this Chapter, Section 1.5) and the need to promote *in situ* conservation (Chapter Two);
- the need to ensure that the genetic diversity of major crops is adequately represented in *ex situ* collections (Chapter Three), and that these collections are secure and available for use (Chapter 4).
- the need to use genetic diversity effectively, *inter alia* through improvement programmes (Chapter Four);
- the need to promote sufficient levels of genetic diversity in crops and breeding lines (this Chapter, Section 1.5, and Chapter Four).

These issues are examined on a crop by crop basis in Annex 2 and explored further in the Chapters indicated above.

With respect to minor crops and under-utilized species, there is a need for greater investment in their conservation and sustainable utilization, in order to broaden the base of agriculture and meet the needs of nation states and local people who are dependent on these species (see Chapter Four).

### Values of PGRFA

Genes and genotypes are valuable because of the agronomic and other qualities they provide. Genetic diversity per se is valuable in that it evens out yield variability, provides insurance against future changes and is a "treasure chest" of as yet unknown resources. It is, however, difficult to quantify these values. Further research is needed in this regard in order to assess these values better. It is also often difficult for those who conserve PGRFA to appropriate the benefits derived from their use.

### Location of PGRFA

Large amounts of diversity are maintained in *ex situ* collections. Diversity *in situ* is often greatest in the areas where the crops were domesticated and developed historically by farmers. These, however, are often different from today's important areas of production for such crops. There is thus great interdependence between regions of the world for PGRFA and a need, therefore, for continued germplasm exchange. Finally, there is a need for more information on the extent of diversity in secondary centres, which are especially important for some crops.

### Genetic vulnerability and genetic erosion

The loss of genetic diversity is widespread. The many forces leading to genetic erosion need to be better understood so that the problem can be addressed more effectively. Furthermore, the relationship between genetic uniformity and genetic vulnerability needs to be better understood. Both genetic vulnerability and genetic erosion are poorly documented, calling for the development of better indicators and measurements.

### An integrated approach to conservation and utilization

The utilization of plant genetic resources is the key to improving agricultural productivity and sustainability and can contribute to socio-economic development, food security and the alleviation of poverty.[126] As described in this Chapter, these vital resources are seriously threatened by erosion. The nature of economic development would seem to be part of the problem, as would the lack of appropriation of the benefits derived. An integrated strategy for the conservation and utilization of PGRFA is called for with the following features:

- **Productivity** - greater use of plant genetic resources will be required to contribute to the productivity increases needed to meet growing demand. This will require continued access to, and exchange of, the world's plant genetic resources.

- **Sustainability** - there is a need to ensure that such use of plant genetic resources is coupled with conservation, both *in situ* and *ex situ*. This will require, *inter alia*, approaches to crop improvement which allow the maintenance of higher levels of diversity in production systems, thereby contributing to reduced genetic vulnerability and less genetic erosion. Additionally, conservation programmes should be clearly linked with utilization efforts and the sharing of benefits, in order to reinforce the sustainability of such programmes.
- **Equity** - those responsible for conserving and developing plant genetic resources should be able to participate fully in the benefits derived from their use. There is thus a need to develop crop improvement approaches to enable farmers in marginal areas, as well as those in high-productivity areas to benefit fully from the utilization of plant genetic resources.

The foregoing assessment illustrates the interrelationship between the three objectives of conserving, utilizing and sharing the benefits of genetic resources and suggests that only by addressing all three in an integrated way can any one objective be achieved sustainably.

■

## Chapter 1 endnotes

[1] 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 (landraces); (iv) wild and weed species, near relatives of cultivated varieties; (v) special genetic stocks (including elite and current breeders' line and mutants)".

[2] FAO (1995) *Report of the Sixth Session of the Commission on Plant Genetic Resources,* 19-30 June 1995. Document CPGR-6/95/REP, para 67.

[3] Heywood VH (ed.) (1995) *Global biodiversity assessment*, p.118. UNEP, Cambridge University Press, UK; Wilson EO (1988) The current state of biological diversity. In: Wilson EO (ed.) *Biodiversity*, p. 3-20. National Academy Press, Washington DC.

[4] Wilson EO (1992) *The diversity of life*, Penguin, London, p. 275.

[5] McNeely JA and Wachtel PS (1988) *Soul of the tiger*. Doubleday, New York; Mooney PR (1983) The law of the seed. *Development Dialogue,* 1-2:1-172.

[6] Data obtained from FAO (1991) *Food balance sheets: 1984-1986 average*. FAO, Rome, 384 pp.

[7] Persley GJ (1990) *Beyond Mendel's garden: biotechnology in the service of world agriculture*. World Bank/ISNAR/ACIAR/AIDAB Study, Commonwealth Agricultural Bureau International, UK, 154 pp.

[8] Prescott-Allen R and Prescott-Allen C (1990) How many plants feed the world? *Conservation Biology*, 4:365-374.

[9] Sugar cane is reviewed in this chapter. However, in many temperate countries, a large proportion of sugar is provided by sugarbeet.

[10] Common bean (*Phaseolus*) provides the largest share of energy intake described as "beans". However, other species also contribute.

[11] Subregional preparatory meeting: South America Report, programme 4.

[12] Subregional preparatory meeting: Europe Report, paras 36, 38; Subregional preparatory meeting: Mediterranean Report, para 41.

[13] Subregional preparatory meeting: Central America, Mexico and the Caribbean. Recommendation of Caribbean Subregion (vii).

[14] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xix).

[15] Subregional preparatory meeting: Southern Africa Report, recommendation (xix); Subregional preparatory meeting: Europe Report, para 38.

[16] Subregional preparatory meeting: North America Report, para 9.

[17] Subregional preparatory meeting: West Africa Report Annex, update using list agreed in Subregional preparatory meeting.

[18] The term "wild" may be misleading because it implies the absence of human influence and management. There is no obvious or strict divide between "domesticated" and "wild" food species; rather it is a continuum resulting from coevolutionary relationships between humans and their environments.

> Many plant species and populations that have been considered to be wild are actually carefully nurtured by people, albeit less intensively than those cultivated in their fields. See Gomez-Pompa A and Kaus A (1992) Taming the wilderness myth. *Bioscience,* 42:271-279, or Posey DA (1995) *Indigenous peoples and traditional resource rights: a basis for equitable relationship*? Green College, Oxford University, U.K., 56 pp.

19 Country Reports Ethiopia, the Sudan; Chambers R, Longhurst R and Pacey A (1981) *Seasonal dimensions to rural poverty*, Frances Pinter, London.

20 Chemical analysis of wild foods eaten in the Sudan has revealed that some are richer in protein, energy, fat or minerals than the cultivated staples, Country Report Sudan.

21 *Inter alia,* Country Reports Armenia, Dominica, Ethiopia, Greece, Guyana, Malaysia, Malawi, Nigeria, Solomon Islands, the Sudan, Zambia.

22 Subregional preparatory meeting: South and East Mediterranean Report, para 16; Subregional preparatory meeting: West Asia Report, paras 15, 17; Subregional preparatory meeting: Southern Africa Report, para 10; Subregional preparatory meeting: Southeast Asia Report, section 1.B.

23 Kiss A (1990) *Living with wildlife: wildlife resources management with local participation in Africa*. World Bank Technical paper 130, Africa Technical Department Series, World Bank, Washington DC.

24 This depends to some extent on whether the species is open- or self-pollinating.

25 Alika JE, Aken'Ova ME & Fatoukan CA (1993) Variation among maize (*Zea mays* L) accessions of Bendel State, Nigeria. Multivariate analysis of agronomic data. *Euphytica,* 66:65 -71; Ceccarelli S, Valkoiun J, Erskine W, Weigland S, Miller R & van Leur JAG (1992) Plant genetic resources and plant improvement as tools to develop sustainable agriculture. *Experimental Agriculture*, 28:89-98; Dennis JV (1987) *Farmer management of rice variety diversity in northern Thailand*. Cornell University, Itahca, NY (Ph.D. thesis); Gepts P & Clegg MT (1989) Genetic diversity in pearl millet (*Pennisetum glaucum* [L] R.Br.) at the DNA sequence level, *Journal of Heredity,* 80:203-208; Jaradat AA (1991) Phenotypic divergence for morphological and yield-related traits among landrace genotypes of durum wheat from Jordan. *Euphytica*, 52:155-164; Mordern CW, Doebley JF & Schertz KF (1989) Allozyme variation in old world races of Sorghum bicolor (*Poaceae*). *American Journal of Botany*, 76:247-255; Tomooka N (1991) Genetic diversity and landrace differentiation of mungbean, *Vigna radiata* (L) Wilczek, and evaluation of its wild relatives (the subgenus Ceratotropis) as breeding materials. *Technical Bulletin of TARC*, 28. Tropical Agricultural Research Centre, Tsukuba, Ibaraki, Japan.

26 Harlan JR (1975) Our vanishing genetic resources. *Science* 188:618–621; Hodgkin T, Rao VR & Riley K (1993) *Current issues in conserving crop landraces* in situ. Paper presented to the on-farm conservation workshop, Bogor, Indonesia, 6-8 December 1993.

27 Bolster, JS (1985) Selection for perceptual distinctiveness: evidence from Aguarana cultivars of *Manihot esculenta*. *Economic Botany,* 39:310-325; Brush SB (1991) Farmer conservation of new world crops: the case of Andean potatoes. *Diversity,* 7:75-79.

28 The term "centre" is commonly used to refer to the areas of origin and/or of diversity of cultivated plants. However, in many cases such areas are quite large, and some scientists have suggested other terms. Harlan JR (1971) Agricultural origins: centers and noncenters. *Science* 21:6.

29 Harlan JR (1976) The plants and animals that nourish man. *Scientific American*, 235:89-97.

30 Juma C (1989) The gene hunters: biotechnology and the scramble for seeds. Zed Books, London, 288 pp.

31 In the case of North America see: Nabhan GP (1989) *Enduring seeds*. North Point Press, San Francisco, US. 225 pp. In the case of Latin America see: Bermejo JEH and Leon J (1994) *Neglected crops: 1,492 from a different perspective*. FAO Plant Production and Protection Series No. 26, FAO, Rome, 341 pp.

32 This figure provides illustrative examples only. Appendix 3 provides a more complete list.

33 Engels JMM, Hawkes JG and Worede M (1991) *Plant genetic resources of Ethiopia*. Cambridge University Press, Cambridge, UK.

34 Article 2 of the Convention on Biological Diversity states that the "Country of origin means the country which possesses those genetic resources in *in situ* conditions" where "*in situ* conditions means conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, where they have developed their distinctive properties".

35 Kloppenburg JR & Kleinman DL (1987) Plant germplasm controversy - analysing empirically the distribution of the world's plant genetic resources. *Bioscience*, 37:190-198.

36 Wood D (1988a) Crop germplasm: common heritage or farmers' heritage? In: Kloppenburg JR (ed.) *Seeds and sovereignty*, Duke University Press. Durham, North Caroline, USA; Wood D (1988b) Introduced crops in developing countries - a sustainable agriculture? *Food Policy*, May 1988, p.167-177.

37 Plucknett DL, Smith NJH, Williams JT and Anishetty NM (1987) *Genebanks and the world's food*. Princeton University Press, New Jersey, US.

38 Op. cit., endnote 36.

39 Op. cit., endnote 35.

40 See Wood D (1988a) op. cit., endnote 36.

41 *Inter alia*, Country Reports Azerbaijan, Cambodia, China, Estonia, Kazakhstan, Kenya, Malawi, Papua New Guinea, Turkmenistan.

42 Francis, CA (1986) *Multiple cropping systems*. Macmillan, New York; 383 pp.

43 Lipton M and Longhurst R (1989) *New seeds and poor people*. Unwin Hyman, London.

44 Wolf EC (1986) *Beyond the green revolution: new approaches for third world agriculture*. Worldwatch paper 1987/1, Worldwatch Institute, Washington DC.

45 Chambers R (1994) Introduction. In: Scoones I and Thompson J (eds.) Beyond farmer first: rural people's knowledge, agricultural research and extension practice, p. xiii: Intermediate Technology Publications, London.

46 FAO (1995) *A fairer future for women*. Women and People's Participation Division, FAO, Rome.

47 Dankelman I and Davidson J (1988) *Women and environment in the third world*, Earthscan, London.

48 Subregional Synthesis Report: West Africa, para 22.

[49] Country Report China.

[50] Berg T, Bjørnstad A, Fowler C and Skroppa T (1991) *Technology options and the gene struggle.* NorAgric occasional paper, Norwegian Centre for International Agricultural Development, Agricultural University of Norway; Woods D (1992) *Options for change: an independent appraisal of CGIAR activities in plant genetic resources.* International Germplasm Associates, Cumbria, UK.

[51] Quisumbing AR, Brown LR, Sims Feldstein H, Haddad L and Pena C (1995) *Women: the key to food security*. Food Policy Report, IFPRI, Washington DC, 22 pp.

[52] Opole M (1992) *Proceedings of an International Conference "The Gene Traders"*. Intermediate Technology Publications, UK.

[53] Subregional Synthesis Report: West Africa, para 22.

[54] Ibid.

[55] Cromwell E and Zambezi B (1991) *The performance of the seed sector in Malawi: an analysis of the influence of organizational structure.* Research Report, ODI, London.

[56] Ferguson AE and Sprecher S (1987) *Women and plant genetic diversity: the case of beans in the central region of Malawi.* Paper presented at the American Anthropological Association Meeting, Chicago, November 18 1987.

[57] Subregional Synthesis Report: Europe, para 9.

[58] Cox TS, Murphy JP and Rodgers DM (1985) *Coefficients of parentage for 400 winter wheat cultivars.* Kansas Agricultural Experiment Station, Manhattan, Kansas, USA.

[59] Fischbeck G (1989) Evaluation of cereals in Europe. In: Brown AHD, Frankel OH, Marshall DR and Williams JT (eds.) *The use of plant genetic resources*. Cambridge University Press, Cambridge, UK.

[60] Kannenberg LW and Falk DE (1993) Models for activation of plant genetic resources for crop breeding programs. *Canadian Journal of Plant Science,* 75:45-53.

[61] Esquinas-Alcazár, JT (1987) Plant genetic resources: a base for food security. *Ceres,* 20:39-45.

[62] Wickens GE, Haq N and Day P (1989) *New crops for food and industry*. Chapman and Hall, London, 444 pp.

[63] Information derived from the International Wheat Information System; and Smale M (1996) personal communication.

[64] Kronstad WE (1986) Germplasm: the key to past and future wheat improvement. In: Smith EL (ed.) *Genetic improvement of yield in wheat,* p. 41-54, Special publication 13, Crop Science Society of America, Madison, Wisconsin.

[65] Kihara H (1983) Origin and history of "Daruma", a parental variety of Norin 10. *Proceedings of the Sixth International Wheat Genetics Symposium,* 6:13-19.

[66] Esquinas-Alcazár JT (1987) Plant genetic resources: a base for food security. *Ceres*, 20:39-45.

[67] Harlan JR (1981) Evaluation of wild relatives of crop plants. *Report of the FAO/UNEP/IBPGR Technical Conference on Crop Genetic Resources*. Rome, 6-10 April 1981.

68 Esquinas-Alcazár JT (1981) Genetic resources of tomatoes and wild relatives. IBPGR-FAO, Rome.

69 Howard HW (1970) *Genetics of the potato* Solanum tuberosum. Logos Press, London.

70 Allard RW (1949) A cytogenetic study dealing with the transfer of genes from *Triticum timopheevi* to common wheat by backcrossing. *Journal of Agricultural Research*, 78:33-64; Knott DR, Ramanujam S (1978) The transfer of genes for rust resistance to wheat from related species. *Proceedings of the fifth International Wheat Genetics Symposium*. Indian Society of Genetics and Plant Breeding, New Delhi.

71 Khush GS and Beachell HM (1972) Breeding for disease resistance at IRRI. In: *Rice breeding*, p. 309-322, IRRI, Los Baños, the Philippines.

72 Doussinalt G, Delibes A, Sanchez-Monge and Garcia-Olmedo F (1983) Transfer of a dominant gene for resistance to eyespot disease from a wild grass to hexaploid wheat. *Nature*, 303:698-700.

73 Prescott-Allen R and Prescott-Allen C (1982) *Genes from the wild. Using genetic resources for food and raw materials*. International Institute for Environment and Development, London, 101 pp.

74 Nachit MM and Ketata H (1986) Breeding strategy for improving durum wheat in Mediterranean rainfed areas. In: *Proceedings of the Fifth International Wheat Conference*, Rabat, Morocco.

75 Maunder AB (1992) Identification of useful germplasm for practical plant breeding programmes. In: Stalker HT and Murphy JP (eds.) *Plant breeding in the 1990s, p. 147-169,* CAB International, UK.

76 Riley R (1989) Plant biotechnologies in developing countries: the plant breeders perspective. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by CTA and FAO, Luxembourg, 26-30 June 1989.

77 Hossain M (1994) Recent developments in Asian rice economy: challenges for rice research. In: *Workshop on Rice Research Prioritization in Asia*, IRRI, Los Baños, the Philippines, 15-22 February 1994.

78 Iltis HH (1988) Serendipity in the exploration of biodiversity: What good are weedy tomatoes? In: Wilson EO (ed.) *Biodiversity*, p. 99, National Academy Press, Washington DC.

79 Studies on rare traits indicate that between 30% and 40% of productivity gains would not have been realized without the existence, evaluation and use of collected landraces. Furthermore, it has been estimated that 10% of the overall gain in rice productivity in South Asia can be attributed to the size and evaluation status of the collections of landraces and related populations used by breeders. The average annual gain is 1.5%, indicating a gain from the material in these collections of about 0.2%, or about US ò150 to ò 200’ million per year. (This is a gross value before the deduction of costs.): Evenson (1994) *The valuation of crop genetic resources preservation, conservation and use*, Commission on Plant Genetic Resources, FAO, (unpublished), 52 pp.

80 Estimates by Dalrymple (1986), Goodman (1985), INTAGRES (1992), OECD (1982) and Tribe (1991) are cited by Mooney PR (1993) Exploiting local knowledge: international policy implications. In: de Boef W, Amanor K, Wellard K & Bebbington A (eds.) *Cultivating knowledge: genetic diversity, farmer experimentation and crop research*, IT Publications, London.

[81] Van Gaasbeek AF, Heijbroek AMA, Vaandrager P and Boers GJ (1994) *The world seed market: developments and strategy.* Rabobank Nederland agribusiness research in association with Ministry of Agriculture, Nature Management and Fisheries, and Agricultural Economic Institute, 54 pp.

[82] Wright BD (1996) *Intellectual property and farmers' rights*, Paper presented at the Symposium on Economics of Conservation and Valuation of Genetic Resources for Agriculture, Universitá di Roma Tor Vergata, Rome, 14 May 1996.

[83] National Research Council (1972) *Genetic vulnerability of major crops.* National Academy of Sciences, Washington DC; NAS 1972.

[84] Vellve R (1992) *Saving the seed: genetic diversity and European agriculture.* Earthscan Publications, London, 206 pp.

[85] Op. cit., endnote 37.

[86] Dalrymple DG (1986) *Development and spread of high-yielding wheat varieties in developing countries*, 7th ed. US Agency for International Development, Washington DC.

[87] Op. cit., endnote 83.

[88] Smale M (1996) personal communication.

[89] Wolfe M (1992) Barley diseases: maintaining the value of our varieties. *Barley Genetics VI*, vol. II, p. 1055-1067.

[90] Hargrove TR, Cabanilla VL and Coffman WR (1985) *Changes in rice breeding programs in Asia.* IRRI Research Paper Series No. 18, IRRI, Los Baños, the Philippines.

[91] By broadening the diversity of resistance genes and "pyramiding" multiple genes from different sources, breeders can strengthen resistance even in genetically uniform varieties.

[92] Fry WE, Godwin SB, Dyer AT, Matusak JM, Drenth A, Tooley PW, Sujkowski LS, Koh YJ, Cohen BA and Spielman LJ (1993) Historical and recent migrations of *Phytophthora infestans*: chronology, pathways and implications. *Plant Disease*, 77: 653-661.

[93] Goodwin SB and Fry WE (1994) The genetic composition of *Phytophthera infestans* populations in the United States during 1994: preliminary report, (unpublished), 31 pp.

[94] Op. cit., endnote 86.

[95] Op. cit., endnote 87.

[96] Sackville Hamilton R (1995) IGER, Wales, personal communication.

[97] Fischbeck G (1981) The usefulness of genebanks - perspectives for the breeding of plants. In: *UPOV Symposium the Use of Genetic Resources in the Plant Kingdom,* Geneva, Switzerland.

[98] Stroebel GA, Stierle, AA, Upadhyay R, Hershenhorn J, Molina G (1993) The phytotoxins of *Mycosphaerella fijiensis* the causative agent of black sigatoka disease, and their potential use in screening for disease resistance. In: *Biotechnology applications for banana and plantain improvement.* Proceedings of a Workshop held in San José, Costa Rica, 27-31 January 1992. INIBAP.

[99] Swanson TM, Pearce DW and Cervigni R (1994) *The appropriation of the benefits of plant genetic resources for agriculture: an economic analysis of the alternative mechanisms for biodiversity conservation*. FAO Commission on Plant Genetic Resources, Background Study Paper No. 1, FAO, Rome.

[100] Roberts RAJ and Dick WJA (1991) *Strategies for crop insurance planning*. FAO Agricultural Services Bulletin No. 86, FAO, Rome. However, most insurance schemes are now of the specific risk type and generally cover only abiotic stresses, such as frost, drought and wind. This is because the basic principle of insurance is the pooling of risks, i.e. the probability of crop failure for any customer (farmer) should be independent of that for anyone else. This is not so when risks are uniform as may be the case for climatic stress, or when cultivars become uniformly susceptible to pests and diseases.

[101] Op. cit., endnote 99.

[102] Strictly, the loss of gene variants or alleles.

[103] Ahn (1994) quoted in Country Report Republic of Korea, Annex 9.

[104] Country Report China.

[105] Subregional Synthesis Report: Southeast Asia, section 1.B.

[106] Subregional Synthesis Report: East Africa, paras 19, 20, 21.

[107] Subregional Synthesis Report: Europe, para 15.

[108] Country Report Federal Republic of Yugoslavia (Serbia and Montenegro).

[109] Country Report Argentina.

[110] Fowler C (1994) Unnatural selection: technology, politics and plant evolution. Gordon and Breach Science Publishers, Yverdon, Switzerland.

[111] Information from Country Reports.

[112] Country Report China.

[113] Subregional Synthesis Report: Indian Ocean Islands, para 23.

[114] Information from Country Reports.

[115] Information from Country Reports.

[116] Information from Country Reports.

[117] Information from Country Reports.

[118] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xx).

[119] Subregional Synthesis Report: Pacific, section 1.B.

[120] Country Report Maldives.

[121] Information from Country Reports.

[122] Information from Subregional Synthesis Report and Country Reports.

[123] Information from Country Reports.

[124] Public goods have the following characteristics. They are non-rival in consumption terms (i.e. consumption of the good by one individual does not preclude consumption by others), and they are non-exclusive (i.e. having provided the good,

> it is impossible, or excessively costly, to operate any mechanism to exclude others). Therefore, national and international management of public goods, including through regulation of exploitation, is generally necessary, to prevent misuse or overuse. Turner RK (ed.) (1993) *Sustainable environmental economics and management*. Belhaven Press, London.

125 Based on Swanson TM, Pearce DW and Cervigni R. op. cit. 99.

126 Its contribution to sustainable agriculture and national development has been recognized as the ultimate objective of PGRFA conservation and use. Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(b); Subregional preparatory meeting: Southern Africa Report, para 11 (i).

# CHAPTER 2
# The State of *In Situ* Management

## 2.1 INTRODUCTION

Traditionally, *in situ* conservation has been used principally for the conservation of forests and of sites valued for their wildlife or ecosystems, whereas *ex situ* conservation has been the predominant approach for the conservation of plant genetic resources for food and agriculture (PGRFA).[1] In recent years, however, the need for integrated conservation strategies for PGRFA based on the complementarity of *in situ* and *ex situ* approaches has become clear. This was emphasized at the United Nations Conference on Environment and Development (UNCED)[2] and was clearly affirmed during the preparatory process for the International Technical Conference,[3] during which it was proposed that increased resources be allocated for *in situ* conservation, especially in developing countries.[4]

In contrast to *ex situ* conservation, *in situ* conservation permits populations of plant species to be maintained in their natural or agricultural habitat, allowing the evolutionary processes that shape the genetic diversity and adaptability of plant populations to continue to operate.[5] In the particular case of on-farm conservation, landraces continue to evolve, influenced by natural selection as well as by selection pressures imposed by the farmer, thus providing opportunities for continuous crop adaptation and improvement. *In situ* conservation can, therefore, be consistent with enhanced PGRFA utilization at the local level and contribute to agricultural development.[6] In this respect, the term "*in situ* management" is perhaps more appropriate.

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."

The need to develop a number of approaches for *in situ* conservation for PGRFA was identified during the preparatory process for the International Technical Conference. These approaches included:

- specific conservation measures for crop wild relatives and wild food plants, particularly in protected areas;[7]
- sustainable management of rangelands, forests and other humanized ecosystems;[8]
- conservation and sustainable utilization of landraces or traditional crop varieties on-farm and in home gardens.[9]

In this Chapter, the status of *in situ* conservation is surveyed for each of these three approaches. Further information on methodologies for *in situ* conservation is given in Annex 1-2 The need for inventories of PGRFA and related information is also reviewed.

## 2.2 INVENTORIES AND SURVEYS

Many countries have recognized the need for a complete national inventory of cultivated plant genetic resources, wild relatives, ecosystems and the traditional knowledge associated with them. Such inventories are needed in order to develop appropriate conservation strategies and to ensure an optimum balance between *in situ* conservation and collecting for *ex situ* conservation.[10]

### Surveys

Many countries specifically cited the need for surveys to determine their present status of local plant genetic diversity.[11] Surveys help to identify areas with high plant or genetic diversity and areas whose genetic diversity is at risk. Surveys may also involve active monitoring of populations of rare and endangered species,[12] and they may be used to determine the genetic vulnerability of existing crops.[13] Furthermore, surveys can be used to compile national collections of indigenous PGR,[14] for which there is a need to evaluate the flora in cultivated areas - home gardens and protected areas such as sacred groves.[15]

The extent of existing survey information varies considerably from country to country. In some, due to the lack of road infrastructure and the inaccessibility of areas of dense forest[16] and mountains, the genetic and ecological diversity is not well known. In other countries, satellite imagery has been used in mapping vegetation.[17]

Inventories of ecosystems have also been carried out to identify sites where specific species can be conserved *in situ*. In Europe, most countries have surveyed and identified endangered species, drawn up "red" lists, and put in place measures to protect these species and their habitats. Only a few countries, however, have specifically surveyed the status of wild species related to crops. These countries include Israel, Portugal, Switzerland and Turkey.

### Inventories

The need for comprehensive inventories of existing diversity that is being conserved both *in situ* and *ex situ* was noted in a number of Country Reports.[18] Inventories are required to assess how representative protected areas and collections[19] are in terms of the total diversity of particular species and, thus, to establish priorities for further collection and conservation. They also help to resolve the problems of excess duplication and redundancy in collections (see Chapter Three), and may help to ascertain the country of origin of samples. The publication of catalogues and the development of databases detailing information on collections are essential parts of inventories and important means of disseminating information on plant diversity.[20] Inventories can also assist in disseminating knowledge on plant varieties and encouraging the use of conserved material.[21]

In addition to inventories, there is a need for an international system of documenting plant genetic resources. This should be based on existing systems, taking into account national, regional and international differences and interests.[22]

### Ethnobiological studies and surveys of indigenous knowledge

The recognition, documentation and use of indigenous knowledge is vital to the safeguarding and utilization of PGRFA.[23] Therefore, there is a need to document traditional knowledge associated with PGRFA. Valuable information relating to plant genetic resources exists within indigenous knowledge systems in many parts of the world (see Box 2.1). This knowledge ranges from traditional uses of plants to strategies for the management and conservation of landraces, pest and disease management, traditional selection and breeding methods, environmental monitoring and early warning systems for ecological change.[24] Such knowledge and practices can be useful in guiding the collection, preliminary evaluation and monitoring of economically important plants, and the development of community-based projects.

## 2.3 CONSERVATION OF PGRFA IN PROTECTED AREAS

Worldwide, protected areas number 9,800 and cover approximately 926 million hectares of the earth's surface.[25] The IVth World Congress on National Parks and Protected Areas, held in Caracas in 1992, encouraged governments to "ensure, through international cooperation, that Protected Areas cover at least 10% of each representative biome by the year 2000".[26] Several countries have already included more than 10% of their territory as Protected Areas.[27]

### Box 2.1 Indigenous knowledge about plant genetic resources for food and agriculture

There are many examples of valuable information within local and indigenous knowledge systems[28] as they relate to plant genetic resources. The keepers of much of this knowledge are often the elders in rural communities. However, due to increasingly rapid cultural change and mass rural-urban migration in the latter half of this century, there is a danger that such knowledge may not be passed on to younger generations and could be lost forever.The following is an annotated list of examples.

**Location of areas of high plant diversity.** Local people may have knowledge not only of the distribution of particular wild plants but may also know of 'sanctuaries' of high diversity which are often actively protected by the communities as sacred groves[29] fulfilling both spiritual and community insurance functions.[30] An understanding of local seed production and exchange systems can help to characterize the origin, genetic base and degree of adaptation of germplasm,[31] while local names of crop landraces have been used to deduce their location and origin. For example, it was possible to trace geographical sources of crops grown in Cuba today using linguistic and historical evidence.[32]

**Classification systems for germplasm.** Local or indigenous knowledge of species and landraces is often systematized in folk classifications[33] which often correspond to scientific classifications, at both the inter-specific[34] and intra-specific[35] levels. There are also numerous cases of the names of landraces reflecting not just appearance but intrinsic qualities such as days to heading and cooking quality.[36] Sorghum landraces with such names as 'milk in my mouth' and 'squirts out honey' identified by Ethiopian farmers as of superior quality were found, upon evaluation by breeders, to have high levels of protein and the amino acid lysine.[37]

**Identification of useful germplasm.** The identification of desirable germplasm involves the screening of different varieties or ecotypes in order to make a choice for use. Evidence shows that farmers can evaluate varieties for desirable characteristics. For instance, farmers in Kordofan, the Sudan, associate sorghum varieties with the type of soil in which they grow best.[38] There is evidence that farmers are aware of differences among landraces in their resistance to pests, and that they have considerable knowledge of the biology of pests and pest control methods.[39] In western Kenya, a local vegetable, *Gynandropsis gynandra,* taken by pregnant women to fortify themselves against dizziness, was found upon laboratory analysis to contain particularly high levels of iron, calcium and vitamin C.[40] Among the Fulbe pastoralists in Africa, the names of grasses change as the grasses mature and their quality as animal fodder changes. The quality of pasture is mainly linked to the taste of milk produced by the

>(continued) **Box 2.1 Indigenous knowledge about plant genetic resources for food and agriculture**

herd feeding on it. Such information is useful in identifying potential forage grasses which are palatable to livestock and humans.[41] Ethnobotanical studies, based on local or indigenous knowledge, have proved valuable in the identification of plants that are potentially useful for veterinary or human medicine.[42]

**Characteristics used in farmers' selection procedures.** There is extensive evidence that selection by farmers is widespread, particularly in developing countries.[43] For instance, the women cultivators of the Aguaruno Jivaro community in northern Peru identify and select cassava cultivars on the basis of characteristics that show the greatest range of phenotypic variation.[44] Panicle harvesting by Mende farmers in Sierra Leone has allowed them to select rices for short, medium and long duration.[45] Mende farmers also manage and select inter-specific hybrids between *Oryza glaberrima* and its wild relatives.[46] It has been found that differences between Cuban and Mexican maize are linked to maize being prepared and eaten in different ways in the two countries which has led farmers to select varieties for different properties in the two countries.[47]

Establishing Protected Areas is the primary means of conserving forest genetic resources, and some countries have identified selected stands as gene reserves. For example, the Royal Forest Department of Thailand has established 100 hectares to conserve *in situ* the best stands of *Pinus merkusii*. The area is actively managed and protected to allow the natural regeneration of this pine species.[48]

Although some *in situ* conservation efforts have focused on forestry species,[49] many Protected Areas lack clearly defined objectives for the protection of ecosystems, agricultural systems, wild relatives of crops, or even threatened forestry species.[50]

Conservation of indigenous wild species of agricultural importance *in situ,* therefore, generally occurs as an unplanned result of nature protection.[51] This is not surprising as most of the world's national parks and other Protected Areas were set up for conservation of wildlife and rarely, if ever, to conserve plants of importance for food and agriculture.

Several Country Reports emphasize the importance of wild plant genetic resources for local food security and future crop improvement. They also stress the need to broaden conventional *in situ* conservation activities to include such plant genetic resources.[52]

A few Reports provide examples of conservation activities in Protected Areas in relation to PGRFA:

- Germany is using its system of nature reserves as a basis for conservation of wild relatives of apples and pears.[53]
- Bulgaria has a project under way on the *in situ* conservation of forages, crop wild relatives and medicinal plants, and the Czech Republic is planning such an activity.[54]
- Turkey has recently initiated a project to conserve, *in situ*, crop-related wild relatives of cereals, horticultural and ornamental flower crops, medicinal plants and forest trees with support from the Global Environment Facility (GEF).[55] The project will also serve to develop and implement a national strategy for *in situ* conservation, and test and develop a new approach for the conservation of genetic diversity of wild crop species.
- In Central Asia, *in situ* conservation for the protection of forest genetic resources of wild fruit trees and shrubs is currently being carried out in Protected Areas. Turkmenistan has 19 such areas covering over 1,000 hectares, Azerbaijan 15 covering 6,501 hectares, and Kyrgyzstan 680 hectares.[56]
- Israel has conducted pioneering research on *in situ* conservation strategies for wild emmer wheat. Based on the concept of "dynamic gene preservation" of interacting populations in the wild, the plants continue to interbreed, forming new genetic combinations, but the genes themselves are, for the most part, preserved as long as the overall system stays in equilibrium.
- *In situ* conservation sites for wild relatives of *Coffea* have been identified in Ethiopia.[57]
- Sri Lanka has one of the oldest and most extensive networks of Protected Areas, extending over 14% of its land area. Wild plants targeted for *in situ* conservation include fruit-crop genetic resources; species with recalcitrant seeds; wild relatives of rice, legumes and spices; and medicinal plants.
- In Brazil, the Centro Nacional de Recursos Genéticos (CENARGEN) has established ten genetic reserves to maintain timber, fruit, nut, forage and palm species and wild relatives of crops such as cassava and peanut.[58]
- In Mexico, genetically unique wild populations of a perennial maize, *Zea diploperennis* have been specifically targeted for conservation within a small section (10 hectares) of the Sierra de Manantlán Biosphere Reserve.[59]

The examples quoted above are rare. Given the importance of wild and semi-wild food plants to the livelihoods of many poor communities, much greater effort is warranted to address the conservation and development needs of PGRFA in Protected Areas and to identify model approaches.[60] Inventories of existing *in situ* conservation sites such as reserves, game parks, national parks, sacred groves, plant sanctuaries and biosphere reserves, also need to be carried out to provide information on their size and location, the important plant resources within them, and the possible threats to their survival.[61]

Strategic plans also need to be developed with regard to wild species of crops and their conservation and use. Many problems exist in this area, not least the inadequate knowledge of the distribution of wild relatives, a lack of clear priorities and methodologies, and insufficient management tools for ensuring minimum viable population sizes of target species.

It has been proposed that a system of *in situ* conservation areas be established where special measures can be taken to conserve biological diversity for food and agriculture.[62] Guidelines would need to be developed for the selection, establishment and management of such areas. Environmentally sound and sustainable development would be desirable in the areas adjacent to the proposed *in situ* conservation areas in order to protect them further.[63] This is in accordance with the biosphere concept promoted by the United Nation Educational, Scientific and Cultural Organization (UNESCO) (see Annex 1).

A number of countries have called for regional and international cooperation and international funding for the *in situ* conservation of wild relatives of crops.[64] The establishment of regional or subregional networks for *in situ* conservation was proposed at some of the preparatory meetings for the International Technical Conference.[65] For example, at the European meeting it was proposed that *in situ* networks with a focus on ecogeographic subregions, such as the Alps, the Carpathian region, the Balkans and the Mediterranean basin be established.[66] A network of *in situ* conservation areas is envisaged as part of the Global System on Plant Genetic Resources for Food and Agriculture (see Chapter Six).[67]

During the preparatory process, the importance of ensuring the active participation and involvement of local communities in the establishment of Protected Areas was stressed in order to help reconcile the sometimes conflicting goals of conservation with the needs of local communities.[68] This concern is reflected in the increasing number of Protected Areas which focus on integrating conservation and development. The increased number of Protected Areas in the World Conservation Union (IUCN) Management Category VI is one manifestation of this concern (see Annex 1).

## 2.4 ECOSYSTEM MANAGEMENT FOR CONSERVATION OF PGRFA OUTSIDE PROTECTED AREAS

Most plant genetic resources of importance for food and agriculture are located outside Protected Areas, in ecosystems such as farms, rangelands and forests. Some of these areas are common property.[69] All of them require an integrated approach to ecosystem management that gives due attention to both conservation and the need to develop productivity and takes into account the existing economic and social constraints.[70] Rangelands, for example, are often subject to overgrazing and other degradation factors.[71] Forests too are often overexploited.

In many countries of the Pacific, the conservation of plant genetic resources is carried out through community control of land and on-farm conservation. In the Solomon Islands, for example, forest lands are often owned by the indigenous inhabitants; the strong conservation ethic in that country and in the territory of Niue helps to ensure that the forest biodiversity upon which the inhabitants depend for their livelihood is conserved.[72]

Several countries also report on the role local communities play in the sustainable management of ecosystems using traditional methods linked to socio-cultural practices. There are sacred forests in many parts of Africa and Asia where clearing, planting of crops, cutting of wood and even harvesting of non-wood products are forbidden.[73]

A number of proposals to improve ecosystem management were made during the preparatory process. These proposals include:

- research and development of sustainable management techniques for harvested wild plants;
- protection of the traditional resource rights of local people to plant genetic resources;[74]
- ensuring that environmental impact assessments of proposals for development projects include an assessment of the impact of such projects on plant genetic resources;[75]
- promoting the exchange of experiences in ecosystem management, particularly through South-South collaboration.[76]

In Central America and Mexico, there has been a major undertaking to prepare inventories of the sub-region's flora while, more recently, ethnobotanical studies of crops and related wild species have been conducted in Protected Areas.[77]

Several countries in Southern Africa are engaged in the mapping of vegetation. For instance, the Malawi Forestry Department, in collaboration with the Swedish Space Corporation, has carried out a forest mapping exercise using satellite imagery to produce a vegetation map. Inventories of forest ecosystems have also been carried out to determine species composition, stocking and structure. This has helped to identify areas where the conservation of particular species can be managed *in situ*. It has also helped in assessing which areas should be set aside as forest reserves. Regional flora and vegetation maps are also useful in identifying areas rich in diversity.[78]

## 2.5 ON-FARM CONSERVATION

Conservation by farmers of landraces and traditional crop varieties differs in important respects from *in situ* conservation of wild material. A landrace has generally been selected to suit the environment in which it is cultivated and to satisfy the particular needs of its growers, such as flavour and cooking qualities. Although there may often be continued gene introgression with wild relatives in the vicinity, landraces are the products of domestication followed by constant development through farmer selection. Their conservation 'on-farm', therefore, requires continuation of the farmer-induced selection processes through which they have been developed and shaped. The traditional knowledge and practical skills which accompany this process are crucial to on-farm management of improvement of PGRFA.

The maintenance, use, and development of plant genetic resources on and near farms offers many opportunities to combine genetic conservation with agricultural development.[79] On-farm conservation, which is a dynamic form of plant genetic resources management, allows the processes of natural and artificial (farmer) selection to continue.

The continued maintenance and use of landraces by farmers is carried out for a number of complex anthropological and socioeconomic reasons.[80] On-farm conservation of crop genetic resources is more prevalent in complex, diverse, risk-prone environments where local livelihoods depend on subsistence farming. There is, however, growing interest in promoting on-farm conservation in areas where agricultural modernization has taken place, such as in Europe and North America. On-farm conservation is especially desirable for crops which are not receiving sufficient attention from the formal sector.

### 2.5.1 Examples of on-farm conservation

In most countries, farmers practise de facto conservation of landraces as part of their farming system, and have done so for centuries. However, it is only in recent years that specific projects and programmes have been initiated to promote, support and develop on-farm conservation.The following are some examples from Country Reports.

In **Europe**, conservation of agrobiodiversity *in situ* and on-farm is under consideration in a number of countries in response to government and public interest in the "greening" of agriculture through the use of more traditional, organic and integrated farming systems. NGOs are active in this area in Austria, France, Germany, Ireland, Norway, Switzerland and the United Kingdom. In Germany and Sweden, agricultural folk museums are prominent in maintaining and making available landraces and old cultivars.[81]

The European Union (EU) has recently established legislation to promote on-farm conservation. EEC Council Regulation No. 2078/92 provides financial aid to farmers for a wide variety of "agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside". In addition, yearly grants (ECU250 per hectare per annum) are given to farmers who initiate five-year undertakings to cultivate and propagate useful plants, adapted to local conditions, which are threatened by genetic erosion.

Overall, the programme aims to promote low-input, environmentally friendly agricultural practices which will also help to reduce rural depopulation within the farming sector. Another Council Regulation establishes a scheme to certify the origin of certain agricultural products and foodstuffs made from landraces and old cultivars.[82]

Formal institutional programmes and projects for on-farm conservation are generally lacking in the **Near East.** Nevertheless, farmers conserve landraces and varieties of many crops originating in the area through traditional methods of crop management and selection. Farmers have found ways of overcoming environmental constraints such as diseases and a harsh climate by growing genetically variable mixtures.

As a result of demographic pressure and concentration on a limited number of improved varieties, however, many of the traditional diversity-based farming systems are disappearing. Landraces and local varieties persist *in situ,* but mainly in isolated and marginal areas.[83] Recognizing this, many countries have identified a need for on-farm conservation programmes.[84] Morocco, for example, is planning an *in situ* programme in cooperation with the International Plant Genetic Resources Institute (IPGRI).

In **Africa**, Ethiopia is probably the country with the most advanced programme of on-farm conservation. Ethiopia's Biodiversity Institute was one of the first government institutions to engage in *in situ* conservation of landraces.[85] The main objective of a project initiated in 1989 through the Seeds of Survival for Africa Programme, funded by a consortium of Canadian NGOs, is the maintenance of crop diversity and the production of food for local consumption and local markets.

The project relies on cooperation between farmers and breeders to restore Ethiopian landraces such as those lost during the droughts of the 1980s. Landraces of the most important crops, including teff, barley, chickpea, sorghum and faba bean, are being redeveloped from stocks stored in the genebank, multiplied and then reintroduced for conservation and improvement on-farm by farmers. A decentralized approach has been adopted in which community seed genebanks provide farmers with a diverse range of crop types. The project is being expanded with support from GEF. Moreover, it has generated great interest, particularly as a result of its high potential for replication in other countries in the region. Eritrea, for example, has shown interest in developing a similar project.[86]

There are few formal *in situ* programmes or projects in Southern Africa. In many countries, however, farmers continue to cultivate local varieties. Some rural communities, for example, prefer the taste, cooking quality and storage characteristics of traditional varieties of pearl millet to the improved varieties. In Angola, farmers have been forced as a result of the war there, to conserve and utilize their landraces *in situ* rather than use exotic seed. NGO and community-based organizations are playing an important role in promoting the conservation and utilization of plant genetic resources among local farmers in Zimbabwe.[87] With support from COMMUTECH and the Swedish Agency for Research and Co-operation in Developing Countries, work has focused primarily on sorghum landraces cultivated by individual farmers, mostly women. Local NGOs are planning to purchase farms for the on-farm conservation and evaluation of traditional crop varieties in cooperation with farmers and the National Plant Genetic Resources Centre.[88]

## Box 2.2 Factors affecting the capacity of farmers and communities to manage PGRFA

Local capacity for PGRFA management can vary greatly between different geographical locations. Three factors strongly influence the capacity of PGRFA management: the existence and integrity of cultural diversity; access to genetic diversity; and the level of exposure to external influ-ence such as agricultural modernization or other socioeconomic changes. Communities located in centres of plant genetic diversity that have managed local PGRFA for centuries more or less uninfluenced by outside developments, have a high capacity to manage PGRFA. Potato farmers in Cuzco, Peru, for example, collectively handle more than 150 varieties on their farms.[89] Farmers in communities with a strong cultural identity and a highly varied agro-ecology, such as the highlands of Sierra Leone, experiment in order to develop desired plant characteristics of African rice.[90] Farmers in Iringa, the United Republic of Tanzania, on the other hand, who have been exposed to agricultural modernization and grow maize originating in other areas, no longer maintain local varieties in a pure form.[91]

The capacity to manage PGRFA also varies considerably within communities and depends on the ethnic group, social status, gender relations and age of the farmer. Different social groups of farmers within a community may use different varieties of the same crop, adapted to optimize performance under each individual former's respective resource constraints. In Zimbabwe, farmers who lack resources to prepare their land early in the season use a higher proportion of early maturing varieties than richer farmers.[92] Some farmers can manage a higher than average number of varieties and risk experimenting with new germplasm. Only the relatively better-off farmers in Usangu Plains in Tanzania, for example, cultivate a low-yielding, but particularly well-flavoured landrace called *"Shingua ya mwali"*, which translated "the neck of a virgin girl in the pre-marrying age".[93]

There are clear gender differences in local PGRFA management. Women are the local seed selectors for the range of criteria required by households, such as taste, colour, smell and cooking time. Where a division of labour exists, women are often responsible for staple or subsistence crops and men for cash crops. Women's concern with the household economy provides a balance to the market-oriented pressures that emphasize high yield and uniformity. In many households, women manage components of the farming system containing high levels of biodiversity, such as home gardens, and make extensive use of gathered species and tree products. Since women often prepare family meals, this influences the variety of crops which they select for the home garden. Therefore, gender analysis is required in order to understand the dynamics of PGRFA management in a given household or community.

The biological features of different types of crops also influence farmers' ability to experiment with local plant genetic resources and to maintain landraces. While it is relatively easy for farmers to maintain a landrace population of a self-pollinated crop such as rice, it is more demanding to maintain a landrace population of a cross-pollinating crop such as maize. Similarly, while it is relatively easy to experiment with landraces of vegetatively propagated crops, it is more difficult to maintain a high physiological quality of planting material for such crops which tend to be affected by the accumulation of viruses and other pathogens.

In West Africa, there is a project which is part of the Community Biodiversity Development and Conservation (CBDC) programme (see Box 2.3) at the Rokpur Rice Research Centre in Sierra Leone, and Burkina Faso is developing its first on-farm conservation project in cooperation with IPGRI. With the exception of millet and sorghum, most crops in West Africa are exotic species originating from other areas, which may, in some cases, limit farmers' capacity for on-farm improvement.

In **Asia**, there are several significant on-farm conservation programmes in Asia, particularly in the Philippines. The NGOs SEARICE and CONSERVE are working with 140 farmer curators in Mindanao on the conservation and testing of rice and maize varieties. There are strong links between *ex situ* and *in situ* conservation, and CONSERVE maintains a back-up collection of 585 rice varieties and 14 maize varieties on a farm within the community from which varieties are distributed to farmers. In a joint NGO/University of the Philippines at Los Banos initiative, the MASIPAG programme promotes on-farm conservation of rice and other crops. MASIPAG also maintains an *ex situ* collection of 400 accessions, of which about half are being sown through the programme nationwide network. In Viet Nam, SEARICE, together with Can Tho University as part of the CBDC, has initiated an on-farm programme involving salt-tolerant rice cultivars in the Mekong Delta.

The Philippines' national programme on plant genetic resources is now becoming involved in on-farm conservation and has initiated ethnobotany projects to study local community interaction and the conservation and utilization of existing species. Consideration is being given to providing incentives to farmers for the conservation of traditional varieties.[94]

Home gardens also constitute a valuable part of the *in situ* conservation system, but their importance for genetic resources conservation is still not widely recognized and few inventories have been carried out. Home gardens are common in many rural areas of Sri Lanka. They usually have a well defined structure with coconut palms and fruit trees predominant at the outer perimeter. Moving inwards, the canopy is progressively reduced by planting spice-crop trees. Vegetables occupy the inner zone, with indigenous yams in drainage areas and ornamental plants near the house. For several perennial fruit crops, such as banana, mango, jackfruit, citrus, avocado, mangosteen, durian, rambutan, guava and papaya, the bulk of the genetic diversity still present in the country is conserved in home gardens.[95]

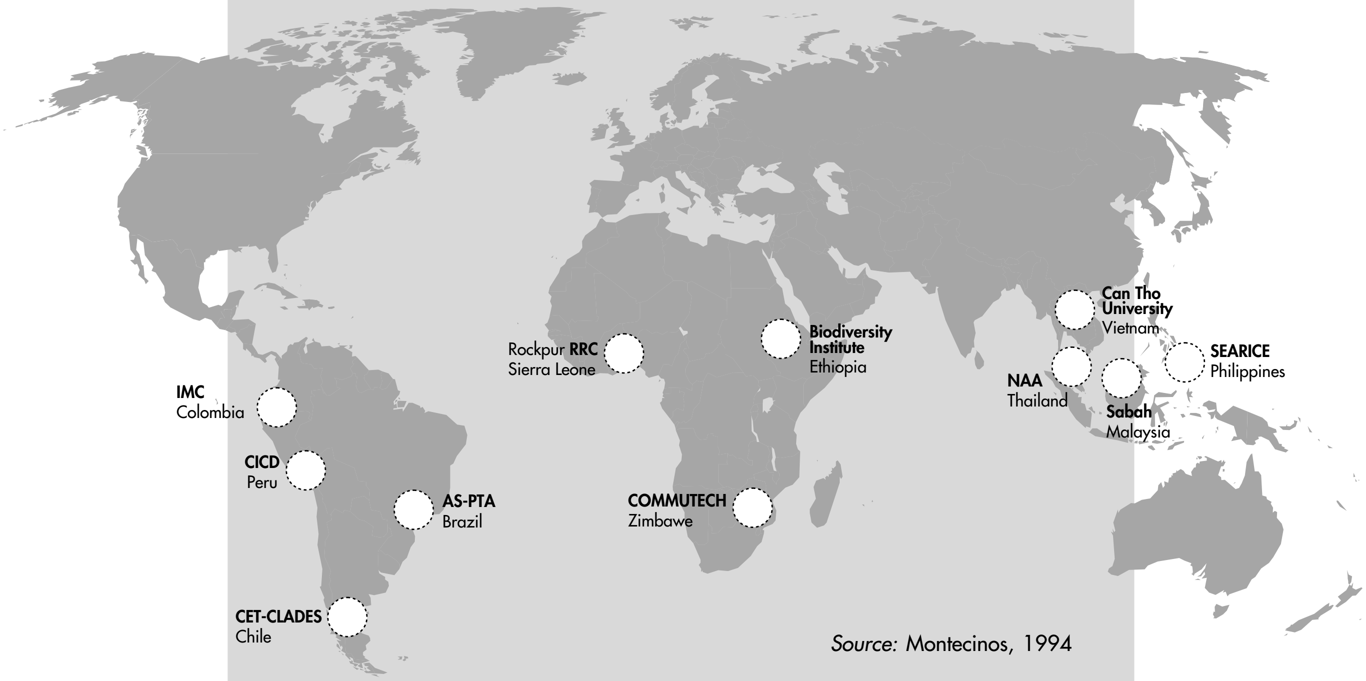
In the **Americas**, several countries in Latin America report on-farm conservation activities. Most involve NGOs, often in collaboration with universities. In Bolivia, there are four major projects related to *in situ* conservation of crops in Protected Areas, mainly involving indigenous communities.[96] These are:

- Programa de Investigación de la Papa, undertaken by the Instituto Boliviano de Tecnología Apropiada;
- Proyecto Conservación de la Biodiversidad de Raices y Tubérculos Andinos, supervised by the Centro Internacional de la Papa (CIP);
- Conservación *in situ* de Raices en Campos de Agricultores y en Formaciones Naturales de La Paz in La Paz;
- Conocimiento y Utilización de Estrategias Campesinas de la Biodiversidad de Papas Nativas in Cochabamba.

In Colombia, *in situ* conservation of crops is also mainly carried out by NGO. The NGO, Instituto Mayor Campesino de Buga, has a project in collaboration with the Universidad Javeriana which is part of the CBDC programme. Other NGOs active in *in situ* conservation include Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria, Asociación de Productores Alternativos de San Andrés de Sotavento, Fundación Herencia Verde, the Organización Indígena de Antioquia, Corporación Penca de Sábila and Programa Semillas. The work of these NGOs includes the rehabilitation, utilization and conservation of landraces of maize, beans, rice, yam, potato and fruit on the small farms where these crops are traditionally grown.[97] In Mexico, research work carried out by the ethnobotanical groups of the Colegio de Postgraduados, Universidad Autónoma Chapingo and Universidad Autónoma de México, established the importance of on-farm conservation through traditional cropping methods in three major projects in the states of Guanajuato, Chiapas, Yucatán, and Veracruz. Studies involved crops such as maize, beans, *Opuntia* as well as medicinal, ornamental and ritual plants. In Peru, CIP has a project in collaboration with the Swiss Agency of International Co-operation which involves on-farm conservation of Andean root and tuber crops by small farmers. The Instituto Nacional de Investigación Agraria also has a programme on *in situ* conservation of Andean root and tuber crops. The faculties of agronomy of the universities of Cuzco, Cajamarca, Ayacucho and Huancayo collaborate in these projects in order to further their understanding of the traditional cropping systems for these crops.

In the United States and Canada, a number of NGOs are involved with on-farm and in-garden conservation of traditional varieties. Some organizations focus on a particular crop or group of crops, such as fruits. The oldest and largest, the Seed Savers Exchange, has a network of several thousand members who conserve and exchange seeds.

**Box 2.3 The Community Biodiversity Development and Conservation Programme**




*Source:* Montecinos, 1994

The Community Biodiversity Development and Conservation Programme brings together eleven local or national partners working at the community level and four global partners - RAFI (Canada), GRAIN (Spain), NORAGRIC (Norway), CPRO-DLO-CGN (The Netherlands). The central objectives of the programme are:

- to provide direct support in strengthening community innovation systems related to the development and conservation of biological diversity;
- to investigate and assess selected community innovation systems related to the conservation and use of Plant Geneti resources;
- to suggest and, where possible, implement ways by which the institutional system can better support community innovation systems.

Projects have been initiated in eleven countries. In some cases, the leading organization is a governmental institution actively involving farmers. In some other cases it is an NGO closely linked to local farming communities working with little or no governmental support.[98] But in all cases, an expected outcome is the increase and strengthening of cooperation between formal and informal, sectors.[99] It has been proposed that national crop development initiatives should be encouraged along the lines of the CBDC Programme.[100]

The Exchange maintains its own *ex situ* genebank facilities and regenerates excessions of thousands of vegetable varieties yearly. The Seed Savers Exchange cooperates with the United States National Seed Storage Laboratory in the conservation of several species. It has also been active recently in promoting grass roots conservation in the Russian Federation, as well as in several European countries. In addition, a number of private seed companies, both large and small, have begun to offer seed of traditional varieties.

Most countries in their Country Reports and through recommendations made at sub-regional meetings called for an expansion of on-farm conservation activities.[101] Although the last five years have been characterized by steady growth in the number of projects and programmes for *in situ* conservation of PGRFA, the projects cited show that few, if any, 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 genebanks which are a form of *ex situ* conservation. IPGRI has initiated a global collaborative project for strengthening the scientific basis of *in situ* conservation of crop plants through national plant genetic resources programmes in nine countries.

### 2.5.2 Strengthening on-farm conservation and development

It is important that on-farm conservation is implemented within the context of agricultural development strategies in order to promote development while conserving diversity.[102] Indeed, in many marginal areas, where the majority of small-scale farmers live, linking the strengthening of on-farm conservation and management of PGRFA to greater use of landraces and their improvement through breeding may be an appropriate strategy for improving farmers' livelihoods as well as maintaining rural populations and preventing degradation of the land.[103] On-farm management is especially useful for maintaining minor vegetables, fruits and other underutilized plant species. The development of markets for such crops, often produced and sold by women, may be important in promoting their conservation and use. On-farm management is also frequently the most suitable method of conservation for fodder species.

A number of activities could be promoted to strengthen on-farm management of PGRFA and contribute to the improvement of farmers' livelihoods:

- support and improvement of farmer-selection of varieties;
- improved links between *ex situ* and *in situ* conservation, including the increased use of landraces which meet farmers' needs from *ex situ* collections;
- promotion of on-farm seed production by farmers and support for informal seed exchange mechanisms;
- modification of policies, as appropriate, to support rather than penalize on-farm management of PGRFA.

All of the above require greater collaboration between the formal sector of PGRFA institutions and the informal community sector. The two systems are potentially compatible, and the creation of innovative links between them may prove the most cost-effective way of using the available resources.

### Improving farmer selection of varieties

While farmers' selection and management techniques may be well adapted to agricultural systems requiring few external inputs, the productivity of such systems is often too low to ensure household food security. To become more productive, local PGRFA management will require assistance from the formal sector to improve access to enhanced germplasm and improved methods of seed selection through extension training.

Farmers actively select varieties on the basis of phenotypic characteristics (easy to observe visually), rather than the associated genotype characteristics used in scientific plant breeding. More work is needed to improve the farmers' ability to select for increased yield and other characteristics that they desire. An example of such "science-aided indigenous plant breeding" is the interdisciplinary work undertaken on rice by the Rokpur Rice Research Centre in Sierra Leone. In addition, a number of NGOs and national programmes have embarked on experimental programmes aimed at enhancing specific qualities of existing elite landraces. One example is the work of the Biodiversity Institute in Ethiopia which screens local landraces of sorghum for drought tolerance and returns the most drought-tolerant varieties to farmers.

During the preparatory process for the International Technical Conference, it was proposed that decentralized approaches to plant breeding be developed in support of these activities.[104] It may be necessary to rethink conventional breeding strategies, especially for the improvement of landraces, and encourage plant breeders to work more closely with farmers in order to meet the needs of poor farmers in marginal environments better.

Farmers can assist in the development of breeding objectives, in germplasm characterization and evaluation, and in testing varieties. Such an approach could make new varieties available quicker[105] and make the system more effective in reaching subsistence farmers.

### Improved links between *ex situ* and in *situ* conservation

The links between de facto conservation by farmers through direct and continuous use and *ex situ* collections of PGRFA has, in the past, been limited to the transfer of germplasm samples from the former to the latter. It has become increasingly apparent that there is far more opportunity for interaction to the mutual benefit of both sectors between PGRFA management and formal *ex situ* conservation.

Continuous selection by farmers ensures that the landraces cultivated are locally adapted. Conservation through direct use, however, does not necessarily provide the security required for long-term preservation. On-farm programmes, therefore, aim to ensure long-term continuation of dynamic conservation by providing adequate incentives to selected farmers for their continued cultivation of a range of local landraces.

In Ethiopia, by the end of 1995, the Seeds of Survival Project had established 22 on-farm conservation sites for a wide range of sorghum landraces, complemented by a number of community *ex situ* collections with samples from the on-farm sites stored in clay pots using traditional seed-storage techniques.

A wide range of storage methods have been developed by farmers around the world for conserving harvested seed. Some examples from West Africa, where traditional methods of preventing pest infestation are still used, are described in Box 2.4.

**Box 2.4 Traditional conservation methods in West Africa**[106]

Cereals such as millet, maize and sorghum are traditionally stored as ears. These are either suspended from trees or roofs, or stored in grain lofts or false ceilings constructed over stoves with branches of wood. There are two kinds of lofts, one for short-term conservation (for use during the current season) and another for medium-term conservation (for use two or three seasons hence). For the first type, branches of a local species of wood are used, e.g. *Guiera senegalensis*. For the second type, the walls are plastered with clay. Peanut, millet and sorghum grains are stored in gourds or in jute or plastic sacks. In the case of cowpeas, the grains are often mixed with ash or wrapped in leaves of the *Khaya senegalensis* tree or the neem tree (*Azadirachta indica*) whose insecticidal properties are well known to peasant farmers. Drums, metal containers and glass jars are all used to conserve the grains.

Farmers growing local crop varieties are not only custodians of PGRFA, but are also extremely knowledgeable about such varieties. There is considerable scope for collecting and documenting information about farmers' PGRFA management practices and adding this knowledge to the data on *ex situ* collected germplasm.[107]

*Ex situ* collections can support farmers' on-farm management of PGRFA. In recent years, *ex situ* collections have also been used as the basis for the reintroduction of PGRFA as a strategy to counter the effects of serious genetic erosion following drought, war and other major destructive events (see Box 2.5).

### Box 2.5 PGRFA rehabilitation programmes

There are numerous examples of local varieties being lost due to war, civil strife and natural disaster. Following are some cases where rehabilitation programmes have been initiated.

- After the civil war in Rwanda in 1994, FAO/CGIAR sponsored the Seeds of Hope initiative aimed at replacing farmers' landraces of beans, sorghum, millet and maize with varieties from genebanks in neighbouring countries and CGIAR centres.
- In Sierra Leone, local varieties are in danger due to the disruption of farming systems, the burning of villages and forced migration of rural populations due to civil disturbances. Current efforts to rehabilitate farming systems include the reintroduction of local rice varieties and other crops from *ex situ* collections.
- Environmental catastrophes, especially drought, have contributed to the loss of genetic diversity. A case in point is the Ethiopian drought of the 1980s which led to the loss of genetic resources, including landraces and wild relatives. Through the Seeds of Survival for Africa Programme, local varieties were reintroduced.
- The genebank of the Islamic Republic of Iran is planning to multiply and help reintroduce seeds of varieties lost as a result of war and abandonment in Afghanistan.
- Kenya's genebank has multiplied seed for the rehabilitation of farming systems in war-torn Somalia.

It has been proposed that genebanks provide landrace germplasm to national programmes, NGOs and farmers' organizations for multiplication and distribution to farmers for their direct use.[108] This could include the reintroduction of traditional varieties, as in the case of Ethiopia and Rwanda, as well as their transfer to new areas with similar agro-ecological conditions.

The following activities are proposed:[109]

- maintenance of *ex situ* collections of local varieties in national, regional and international genebanks;
- complementary conservation strategies, employing both *in situ* and *ex situ* methods for greater security;
- establishment of an early warning system by national co-ordinators to monitor genetic erosion of PGRFA, both *in situ* and *ex situ*, using traditional knowledge as well as modern scientific approaches;[110]
- launching of conservation programmes in neighbouring countries and similar agro-ecological regions in an effort to increase the number of potential partners.

Furthermore, it was proposed that special mechanisms be developed to mobilize resources and action campaigns to avert rapidly the adverse consequences to plant genetic resources in cases of drought, war and other catastrophes.[111] No such capacity exists today and institutional responsibilities are unclear.

### Promotion of on-farm seed production

Informal farmer-to-farmer exchange mechanisms are often effective in providing farmers with well adapted and physiologically acceptable planting material.[112] Many countries, in fact, note the importance of such farmer to farmer seed exchange mechanisms in their Country Reports.[113] Such local seed multiplication and community seed exchange, however, are limited in scale and not always effective. In addition, the formal seed sector, whether private or public, has generally not been able to provide the majority of farmers in developing countries with appropriate improved planting material either (see also Chapter Four).[114] Recent studies indicate that a promising solution may lie in supporting small-scale seed production and distribution enterprises at the farm and village levels.[115] The use of seeds of traditional varieties can be encouraged by supporting their local production and storage. Recognizing this, it was proposed that on-farm seed production and informal seed exchange mechanisms be promoted to complement the formal seed distribution system.[116]

### Policy framework

The need to integrate on-farm conservation activities with national policies was also recognized during the Technical Conference's preparatory process. It was, therefore, recommended that policies and regulations which promote sustainable on-farm conservation of crops be considered.[117]

In recent decades, agricultural policies have favoured the adoption of high-input technology packages which include modern crop varieties. However, in some countries, structural adjustment programmes have resulted in increased production costs when using modern varieties. As a consequence of this and other factors, farmers have sometimes reverted to the cultivation of traditional varieties. In Estonia, for example, old grain cultivars, which are more adapted to extensive farming than the newer varieties, are regaining their earlier importance with the decreased use of mineral fertilizers. Similarly, in Zambia, with the liberalization of the economy in 1991 and the withdrawal of government subsidies for agricultural production, the area planted with high-input crops such as maize, wheat and cotton has decreased and the cultivation of traditional crops may be expected to increase.[118]

It has been proposed that agricultural and economic policies be analysed for their effect on the conservation and use of PGRFA. For example, the sub-regional meeting for Europe recommended that EU legislation on marginal agricultural areas and the seed trade be reviewed to evaluate its effect on plant genetic resources conservation and use and, where appropriate, that legislation be adapted specifically to promote on-farm conservation for areas rich in diversity.[119]

Legislation regulating variety release, seed certification and plant breeders' rights (which generally include requirements for distinctness, uniformity and stability) may sometimes hinder the utilization of diverse genetic material, including landraces. Some sub-regional meetings recommended that countries review their regulatory frameworks for their effect on the conservation and use of plant genetic resources, and revise them to promote the creation of special categories to allow for the distribution and commercialization of landraces.[120] In addition, credit and marketing support policies can provide incentives for the production of landraces and underutilized crops.

The use and maintenance of traditional varieties by farmers is also affected by policies on land tenure and land use. At present, few countries provide incentives to farmers to support on-farm management of their landraces, however, proposals for such incentives have been put forward in India, the Philippines, the United Republic of Tanzania[121] and the EU.

The importance of traditional knowledge and the contribution of indigenous and rural communities to the conservation and enhancement of plant genetic resources are seldom fully recognized or appreciated. This lack of recognition applies especially to the contribution made by women. Programmes that improve women's quality of life and support the social, economic and cultural values of local communities should be promoted.[122] These programmes should also support preservation of indigenous knowledge of plant genetic resources.

At the international level, mechanisms for compensation and/or recognition of farmers for their contributions to conserving and developing PGRFA continue to be discussed. Such discussions at FAO and the CBD, for example, could lead to the provision of incentives for on-farm management.

### Research needs

The following research needs were identified during the preparatory process:

- socio-economic studies;[123]
- research on farming systems to identify and analyse limiting factors and guide strategic interventions to improve the situation of farmers;[124]
- analysis of selection criteria and methods used by farmers in order to provide them with varieties more suited to their needs;[125]
- studies on conservation biology, including the monitoring of changes over time in the genetic diversity of landraces;[126]
- information systems and descriptor lists for *in situ* and on-farm plant genetic resources.[127]

## 2.6 ASSESSMENT OF MAJOR NEEDS FOR *IN SITU* MANAGEMENT OF PGRFA

A number of needs can be identified in relation to *in situ* conservation and improvement of PGRFA, whether in Protected Areas, on farms, or through ecosystem management outside Protected Areas and farms.

### Inventories and surveys

National and, in some cases, regional inventories of PGRFA are required to guide national conservation strategies, including determination of the optimum balance between *in situ* conservation and collecting for *ex situ* conservation.[128] Inventories of existing Protected Areas and their present value and potential for the planned conservation of crop wild relatives and other PGRFA are also needed. Finally, there is a need to document indigenous knowledge of traditional varieties and wild PGRFA.[129]

### Research needs

Scientific understanding of the *in situ* conservation and use of PGRFA is still at an early stage. Further work is needed with regard to ecological research, the development of protocols for conservation of wild relatives in Protected Areas, ethnobotanical research and studies of farmer management of PGRFA.

## Conservation networks

A network of *in situ* conservation areas is envisaged as part of the Global System on Plant Genetic Resources for Food and Agriculture. There is a need to clarify the nature of this network. It may include a series of Protected Areas selected for the conservation of crop wild relatives and other wild PGRFA.[130] Regional and sub-regional networks could be developed to facilitate international collaboration with a special focus on on-farm conservation.

## Sustainable ecosystem management strategies

There is a need for sustainable management strategies for the management of forests and rangelands including, in particular, common property resources. Specific approaches need to be identified for the sustainable harvesting of wild food plants and underutilized species with commercial potential.

## Participation of local communities

In recognizing the necessity of reconciling conservation priorities with the socioeconomic needs of local communities, farmers and communities will need to be involved in *in situ* conservation as much as possible.[131] Such participation applies both to the establishment of Protected Areas[132] and to ecosystem management.[133] Similarly, the full involvement of farmers in the design and implementation of on-farm strategies for conservation and improvement should be facilitated.[134]

## Support for on-farm management

In the foreseeable future, on-farm management and improvement of PGRFA will continue to be a principal means of conserving and improving these resources. Such efforts will involve large numbers of people especially in agriculturally marginal areas. Recognizing that conservation can only be achieved through sustainable utilization of PGRFA, the following major needs have been identified:

- promotion and improvement of farmer selection of varieties;[135]
- support for small-scale seed production and distribution enterprises;[136]
- facilitation of access to a wider range of planting material, including the provision of landraces stored *ex situ* for multiplication and distribution;
- development of markets for products originating from traditional and underutilized varieties and crops;[137]
- appropriate changes to the national and international policy frameworks to support on-farm management of PGRFA.

**Rehabilitation mechanisms**

In addition to the above, a mechanism is required to enable the rapid reintroduction of diverse planting material to farming systems that have suffered drought, war or other catastrophes.

**Policy framework**

There is a need for *in situ* conservation programmes to be integrated with national development plans and policies.[138] There is also a need to review and adapt agricultural development policies and regulatory frameworks for variety release and seed certification to understand their impact on PGRFA.

**Institutional linkages**

*In situ* conservation often involves institutions other than those that have prime responsibility for *ex situ* conservation. At the government level, ministries responsible for forestry and environment are often responsible for *in situ* conservation, while *ex situ* conservation is usually the responsibility of the Ministry of Agriculture. In addition, NGOs and grassroots associations often play an important role in *in situ* management.[139] Therefore, there is a need for effective coordination, through national committees for example, to strengthen linkages between formal and informal institutions.[140] Regional linkages and coordination will also be helpful in many cases.

**Towards integrated strategies for the conservation and use of PGRFA**

*In situ* and *ex situ* conservation approaches can and should be complementary, and each should enhance the relative advantages of the other (see Annex 1-2).[141] New mechanisms need to be established to create synergies between the two methods and promote a truly integrated conservation programme. In addition, innovative links are required between conservation and utilization of PGRFA. Finally, there is a need to increase significantly the utilization of what is conserved, be it *in situ* or *ex situ*. Therefore, to build an integrated global conservation system, adequate funding will need to be mobilized, new organizational procedures developed, and formal and informal sectors will have to work more closely with farming communities.

■

## Chapter 2 endnotes

1 Subregional Synthesis Report: Europe, para 86.

2 Convention on Biological Diversity and Agenda 21 *Programme of Action for Sustainable Development*, Chapters 14(G) and 15.

3 Subregional preparatory meeting: Europe Report, para 36(a); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii).

4 Subregional preparatory meeting: Europe Report, para 37(c); Sub-regional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii).

5 Frankel OH and Soule ME (1981) *Conservation and Evolution*. Cambridge University Press, New York.

6 Subregional preparatory meeting: Southern Africa Report, recommendation (xiv).

7 Subregional preparatory meeting: South America Report, para 4; Subregional preparatory meeting: West and Central Africa Report, para 9.

8 Subregional preparatory meeting: Southern Africa Report, recommendation (xiv); Subregional preparatory meeting: West and Central Africa Report, para 9.

9 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii); Subregional preparatory meeting: Southern Africa Report, recommendation (xiv); Subregional preparatory meeting: West and Central Africa Report, para 9.

10 Subregional Synthesis Report: West and Central Africa, para 105; Subregional Synthesis Report: East Africa, para 130; Subregional preparatory meeting: Southern Africa Report, recommendation (xv); Subregional preparatory meeting: South America Report, principle area of action IV, (a, i); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 2; Subregional preparatory meeting: Central and West Asia Report, para 42; Subregional preparatory meeting: Europe Report, recommendation 40(a); Subregional preparatory meeting: Mediterranean Report, recommendation (x).

11 These include, Country Reports Argentina, Austria, Central African Republic, Colombia, China, Cook Islands, Dominica, Egypt, Eritrea, Estonia, Ethiopia, Gabon, Jordan, Kenya, Malawi, Mauritius, Mozambique, the Niger, Nigeria, Guyana, Haiti, Saint Lucia, the Sudan, Sweden, Trinidad and Tobago, United Republic of Tanzania, United Republic of Uzbekistan.

12 Country Report South Africa.

13 Country Report Federal Republic of Yugoslavia (Serbia and Montenegro).

14 Country Report Lithuania.

15 Country Report Nigeria.

16 Country Report Gabon.

17 Subregional Synthesis Report: Southern Africa, para 55.

18 See Country Reports Austria, Canada, Costa Rica, Cyprus, Germany, Grenada, Guatemala, India, Ireland, Jamaica, Malawi, Mexico, Nigeria, Poland, Spain, United States.

19 Country Reports Germany, Canada.

[20] Country Report Cyprus.

[21] Subregional preparatory meeting: Europe Report, para 34.

[22] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xiv); Subregional preparatory meeting: Southern Africa Report, recommendation (xv).

[23] Subregional Synthesis Report: East Africa, para 154.

[24] Ibid.

[25] IUCN (1994) *1993 United Nations List of National Parks and Protected Areas*. Prepared by WCMC and CNPPA. IUCN, Gland, Switzerland and Cambridge, UK, 315 pp.

[26] IUCN (1993) *Parks for life: Report of the IVth World Congress on National Parks and Protected Areas*. Recommendation 16. IUCN, Gland, Switzerland.

[27] Pimbert MP and Pretty JN (1995) *Parks, people and professionals: putting "participation into protected area management"*. United Nations Research Institute for Social Development Discussion Paper DP 57, 2 pp.

[28] Warren D, Slikkerveer L and Titilola S (1989) I*ndigenous knowledge systems: implications for agriculture and international development*, p. 21-32. Studies in Technology and Social Change No. 11, Technology and Social Change Program, Iowa State University, Ames, USA.

[29] Raishankar T, Vedaalli L, Nambi A and Selvam V (1994) *Role of tribal communities in the conservation of plant genetic resources*. MS Swaminathan Research Foundation, Centre for Research on Sustainable Agricultural and Rural Development, Madras, India; Khalil MH, Reid WV and Juma C (1992) *Property rights, biotechnology and genetic resources*. ACTS Press, Nairobi.

[30] Chambers R (1990) *Microenvironments unobserved*. Gatekeepers Series No. 22, IIED, London.

[31] Cromwell EA (1990) *Small farmer seed diffusion mechanisms: lessons from Africa, Asia and Latin America*. ODI Agricultural Research and Extension Network Paper No. 21, ODI, London.

[32] Esquivel M and Hammer K (1988) The "conuco" - an important refuge of Cuban plant genetic resources. *Kulturpflanze,* 36:451-463.

[33] Berlin B (1992) *Ethnobiological classification: principles of categorization of plants and animals in traditional societies*. Princeton University Press, New Jersey, US; Berlin B, Breedlove DE, and Raven PH (1974) *Principles of Tzeltal plant classification*. Academic Press, New York.

[34] Alcorn JB (1984) *Huastec Mayan ethnobotany*. University of Texas Press, Austin, US.

[35] Quiros CF, Brush SB, Douches DS, Zimmerer KS and Huestis G (1990) Biochemical and folk assessment of variability of Andean cultivated potatoes. *Economic Botany,* 44:254-266.

[36] Boster JS (1984) Classification, cultivation and selection of *Aguaruna* cultivars of *Manihot esculenta* (Euphorbiaceae). In: Prance GF and Kallunki JA (eds.) *Ethnobotany in the neotropics. Advances in Economic Botany,* New York Botanical Garden, New York, 1:34-47.

[37] Brhane G and Yilma K (1979) The traditional culture and yield potential of the Ethiopian high lysine sorghums. *Ethiopian Journal of Agricultural Science*, 1:29-40.

[38] Coughenor CM and Nazhat SM (1985) *Recent changes in villages and rainfed agriculture in North Central Kordofan: communication process and constraints*. Institute of Agriculture and Natural Resources, Nebraska Report No. 4, International Sorghum/Millet CRSP. University of Nebraska, Lincoln, US.

[39] Altieri MA (1993) Ethnoscience and biodiversity: key elements in the design of sustainable pest management systems for small farmers in developing countries. *Agriculture, Ecosystems and Environment,* 46:257-272; Box L (1987) *Experimenting cultivators: a methodology for adaptive agricultural research*. Agricultural Administration (Research and Extension) Network Discussion Paper No. 23, ODI, London.

[40] Opole M (1991) Women's indigenous knowledge base in the translation of nutritional and medicinal values of edible local plants in western Kenya. In Prah KK (ed.) *Culture, gender, science and technology in Africa*, p. 81-96. Harp Publications, Windhoek, Namibia.

[41] Bonfiglioli AM (1992) *Pastoralists at a crossroads. Survival and development issues in African pastoralism*. UNICEF/United Nations Sudano-Sahelian Office Project for Nomadic Pastoralists in Africa, Nairobi.

[42] Schultes RE (1986) Ethnopharmacological conservation: a key to progress in medicine. *Opera Botanica*, 92:217-224; Waterman PG (1989) Bioactive phytochemicals - the search for new sources. In: Wickens GE, Haq N and Day P (eds.) *New crops for food and industry*, p. 378-390. Chapman and Hall, London.

[43] Fujisaka S, Elliot P, Jayson E and Dapusala A (1993) Where there has been no "Green Revolution": farmers' upland rices and related knowledge in Mindanao, the Philippines. In: *Indigenous knowledge and sustainable development*, p. 96-110. International Institute of Rural Reconstruction, Silang, the Philippines; Brush SB (1991) Genetic diversity and conservation in traditional farming systems. *Journal of Ethnobiology,* 35:70-88; de Boef W, Amanor K ,Wellard K and Bebbington A (1993) *Cultivating knowledge. Genetic diversity, farmer experimentation and crop research*, p. 89-95. Intermediate Technology Publications, London; Clawson DL (1985) Harvest security and intraspecific diversity in traditional tropical agriculture. *Economic Botany*, 35:70-88.

[44] Boster JS (1985) Selection for perceptual distinctiveness: evidence from Aguaruna cultivars of *Manihot esculenta*. *Economic Botany,* 39:310-325.

[45] Longley C and Richards P (1993) Selection strategies of rice farmers in Sierra Leone. In: de Boef W, Amanor K, Wellard K and Bebbington A (eds.) *Cultivating knowledge. Genetic diversity, farmer experimentation and crop research*, p. 51-63. Intermediate Technology Publications, London.

[46] Richards P (1993) *Culture and community values in the selection and maintenance of African rice*. Paper presented at the conference on Intellectual Property Rights and Indigenous Knowledge, Granlibakken, Lake Tahoe, USA, 5-10 October 1993.

[47] Xolocotzi EH (1987) Experiences leading to a greater emphasis on man in ethnobotanical studies. *Economic Botany*, 41:6-11.

[48] Country Report Thailand.

[49] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 5.

[50] Ibid.

[51] Subregional Synthesis Report: Europe, para 86.

[52] Country Reports Albania, Canada, Czech Republic, France, Germany, India, Mauritius, Mongolia, Poland, Portugal, Turkey, United Kingdom.

[53] Schlosser S (1985) The use of nature reserves for *in situ* conservation. *Plant Genetic Resources Newsletter*, 61:23-25.

[54] Subregional Synthesis Report: Europe, para 86.

[55] Ibid.

[56] Subregional Synthesis Report: Central Asia, section 2.C.

[57] Country Report Ethiopia; Subregional Synthesis Report: East Africa, para 78.

[58] Giacometti DC and Goedert CO (1989) Brazil's National Genetic Resources and Biotechnology Center preserves and develops valuable germplasm. *Diversity*, 5:8-11.

[59] Russell NC (1989) Guadalajara hosts international symposium on *Zea diploperennis* and the conservation of plant genetic resources. *Diversity*, 5:8-9.

[60] Subregional Synthesis Report: Europe, para 118; Subregional preparatory meeting: South America Report, principle area of activity IV: b(iv).

[61] Subregional Synthesis Report: East Africa, para 130.

[62] Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 32 (1).

[63] Ibid.

[64] Subregional preparatory meeting: Europe Report, para 37(c); Country Reports Costa Rica, Ecuador, the Philippines.

[65] Subregional preparatory meeting: South America Report, programme 4.4, activity 4.4.1; Subregional preparatory meeting: Europe Report, para 37(d).

[66] Subregional preparatory meeting: Europe Report, para 37(e).

[67] FAO (1995) P*rogress Report on the Global System on the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture*. Document CPGR-6/95/4 of the Sixth Session of the FAO Commission on Plant Genetic Resources, 19-30 June 1995, FAO, Rome.

[68] Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 31.

[69] Pimental D, Stachow U, Tackacs DA, Brubaker HW, Dumas AR, Meraney JJ, O'Neil JAS and Onsi DE (1992) Conserving biological diversity in agricultural/ forestry systems. *BioScience*, 42:354-362.; 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.

[70] Subregional Synthesis Report: West Asia, para 93.

[71] Subregional preparatory meeting: Mediterranean Report, para 45.

[72] Subregional Synthesis Report: Pacific, section 2; Subregional Synthesis Report: Southeast Asia, section 2.

[73] Subregional Synthesis Report: West Africa, para 59.

[74] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, paras 13(b), 14(ix), 14(xii).

[75] Subregional preparatory meeting: West and Central Africa Report, para 51.

[76] Subregional preparatory meeting: West and Central Africa Report, para 50.

[77] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 5.

[78] Subregional Synthesis Report: Southern Africa, para 55.

[79] Subregional preparatory meeting: Mediterranean Report, para 89.

[80] Subregional preparatory meeting: Mediterranean Report, para 39.

[81] Subregional Synthesis Report: Europe, para 88.

[82] EEC Council Regulation No. 2082/92.

[83] Subregional Synthesis Report: South and East Mediterranean, para 17.

[84] Subregional Synthesis Report: West Asia, para 93

[85] The Plant Genetic Resources Centre of Ethiopia.

[86] Subregional Synthesis Report: East Africa, para 79.

[87] Holle (1995) personal communication, CIP, Peru.

[88] Richards P (1989) Farmers also experiment: A neglected intellectual resource in African science. *Discovery and Innovation*, 1:19-25.

[89] Friis-Hansen E (1995) *Seeds for African peasants*. Scandinavian African Institute, Uppsala, Sweden.

[90] Ibid.

[91] Friis-Hansen E *Plant genetic resource management in Tanzania*. Centre for Development Research, Copenhagen.

[92] Country Report Zimbabwe.

[93] Subregional Synthesis Report: Southern Africa, paras 56, 57.

[94] There is a pending senate bill that aims to protect community intellectual property rights, thus acknowledging the innovative contribution made by local communities and indigenous cultures to the conservation and development of plant genetic resources. See Country Report the Philippines.

[95] Country Report Sri Lanka.

[96] Country Report Bolivia.

[97] Country Report Colombia.

[98] NGOs working at the local/national level are: Community Technology Development Association (COMMUTECH), Zimbabwe; Centro de Educación y tecnología (CET) Chile, on behalf of the Latin American Consortium on Agro-ecology and Development (CLADES); The South East Asian Regional Institute for Community Development (SEARICE), the Philippines; Assesoria e Servicios a Projetoc emmAgricultura Alternative (AS-PTA), Brazil; Centro de Investigación y Capacitación (CICD), Peru; Instituto Mayor Campesino (IMC) Colombia; Partners for Community Organization of Sabah, Malaysia; and Non-Agriculture Association, Thailand.

> National research organizations are Can Tho University, Viet Nam; Biodiversity Institute, Ethiopia; and Rokpur Rice Research Centre, Sierra Leone. Global partners include the Centre for Genetic Resources (CPRO-DLO-CGN), the Netherlands, the Norwegian Centre for International Environment and Development Studies (Noragric), Norway; and the NGOs Genetic Resources Action International (GRAIN), and Rural Advancement Fund International (RAFI).

99 Montecinos C (1994) Bringing farmer and non-farmer breeders together. *Seedling*, December 1994, GRAIN.

100 Subregional preparatory meeting: West and Central Africa Report, para 45.

101 Subregional preparatory meeting: West and Central Africa Report, para 49; Subregional preparatory meeting: Europe Report, para 37(g); Subregional preparatory meeting: Southern Africa Report, recommendation (xiv); Subregional preparatory meeting: Central and West Asia Report, para 26; Subregional preparatory meeting: East Asia Report, para 21; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii); Subregional preparatory meeting: Mediterranean Report, recommendation (xi); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 5.

102 Subregional preparatory meeting: Mediterranean Report, para 39.

103 Subregional preparatory meeting: Mediterranean Report, para 31.

104 Subregional preparatory meeting: Central and West Asia Report, para 27.

105 Subregional preparatory meeting: Mediterranean Report, para 40; Subregional preparatory meeting: Central and West Asia Report, para 27; Subregional preparatory meeting: West and Central Africa Report, para 45; Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 31; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 5.

106 Subregional Synthesis Report: West Africa, para 65.

107 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*, p. 345-366. Commonwealth Agricultural Bureaux International; Oxford, UK.

108 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xix); Subregional preparatory meeting: Southern Africa Report, recommendation (xiv).

109 Subregional preparatory meeting: West and Central Africa Report, para 39.

110 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xv).

111 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xvi).

112 Cromwell E and Wiggins S (1993) *Sowing beyond the state: NGOs and seed supply in developing countries*. ODI, London, 143 pp.; Venkatesan V (1994) *Seed systems in sub-Saharan Africa: issues and options*. World Bank Discussion Papers, Africa Technical Department Series, No. 266, World Bank, Washington DC, 112 pp.

[113] Country Reports Bangladesh, Nepal, Papua New Guinea, Sri Lanka, Surinam, United Republic of Tanzania, Zambia.

[114] Op. cit., endnote 112.

[115] See Cromwell and Wiggins op. cit., endnote 112.

[116] Sub-regional preparatory meeting: Southern Africa Report, recommendation (xx).

[117] Subregional preparatory meeting: Central and West Asia Report, para 27; Subregional preparatory meeting: Europe Report, para 37(g).

[118] Subregional Synthesis Report: Southern Africa, para 29.

[119] Subregional preparatory meeting: Europe Report, para 37(g).

[120] Subregional preparatory meeting: Europe Report, para 37(g).; Subregional preparatory meeting: Mediterranean Report, para 42; Subregional preparatory meeting: Southern Africa Report, recommendation (xxi).

[121] The Tanzanian Government is contemplating establishing a Farmers' Rights Fund in recognition of the important role played by farmers as custodians of traditional cultivars of plants. See Subregional Synthesis Report: Southern Africa, para 30.

[122] Subregional preparatory meeting: North America Report, para 6(d).

[123] Subregional preparatory meeting: Central and West Asia Report, para 27.

[124] Subregional preparatory meeting: Mediterranean Report, para 39.

[125] Subregional preparatory meeting: West and Central Africa Report, para 9; Subregional preparatory meeting: Central and West Asia Report, para 27.

[126] Subregional preparatory meeting: Mediterranean Report, para 39; Subregional preparatory meeting: Central and West Asia Report, para 27.

[127] Country Report Germany.

[128] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xvii); Subregional preparatory meeting: Southern Africa Report, recommendation (xv); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 2; Subregional preparatory meeting: North America, para 12(a); Subregional preparatory meeting: South America Report, area of activity 4.1; Subregional preparatory meeting: Central and West Asia Report, para 41; Subregional preparatory meeting: Mediterranean Report, recommendation (x).

[129] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xiv); Subregional preparatory meeting: Southern Africa Report, recommendation (xv).

[130] Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 32(1); Subregional preparatory meeting: South America Report, programme 4.4; Subregional preparatory meeting: Europe Report, para 37(c).

[131] Subregional preparatory meeting: West and Central Africa Report, para 50; Subregional Synthesis Report: East Africa, para 75.

[132] Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 32 (1).

[133] Subregional preparatory meeting: West and Central Africa Report, para 9.

[134] Subregional preparatory meeting: Southern Africa Report, recommendation (xiv).

[135] Subregional preparatory meeting: Mediterranean Report, para 40; Subregional preparatory meeting: South America Report, programme 4.6; Subregional preparatory meeting: Central and West Asia Report, para 27; Subregional preparatory meeting: West and Central Africa Report, para 45; Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 31; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 5.

[136] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 7; Subregional preparatory meeting: Southern Africa Report, recommendation (xx).

[137] Subregional preparatory meeting: South and Southeast Asia and the Pacific Report, para 32 (3, iv).

[138] Subregional preparatory meeting: Europe Report, para 36(a).

[139] Subregional preparatory meeting: Southern Africa Report, recommendation (xiv).

[140] Subregional preparatory meeting: Europe Report, para 24(a); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13 (c).

[141] Office of Technology Assessment (1987) *Technologies to maintain biological diversity*. Report OTA-F-330. US Government Printing Office, Washington, DC.

# CHAPTER 3
# The State of *Ex Situ* Conservation

## 3.1 INTRODUCTION

Until recently, most conservation efforts, apart from work on forest genetic resources, have concentrated on *ex situ* conservation, particularly seed genebanks. Plant collecting and *ex situ* conservation, especially in botanical gardens, have a long history dating back several hundred years. In 1963, the Twelfth Session of the FAO Conference established a Panel of Experts on Plant Exploration to advise the Organization and set international guidelines for the collection, conservation and exchange of germplasm. This panel strongly promoted *ex situ* conservation of crop genetic resources. Great emphasis was placed on germplasm collecting during the 1970s and 1980s (see Section 3.2). Today, as a result, there are a large number of genebanks and germplasm collections around the world.

It is estimated that existing global *ex situ* collections contain approximately 6 million accessions. This figure is based on the FAO World Information and Early Warning System on Plant Genetic Resources (WIEWS)[1] database as well as on information provided in the Country Reports. The total includes many working collections of plant breeders as well as collections established specifically for long-term conservation.[2] No definitive information exists as to the distribution of accessions between collections intended primarily for conservation (i.e. base collections: see Annex 1-2) and those that are available for distribution (i.e. in active collections) or are in breeders' working collections. A rough estimate, based on information provided in Country Reports, suggests that perhaps between half and two-thirds, that is 3 to 4 million accessions, are in base collections. There is however, duplication within and between collections (see Section 3.5), and the number of unique accessions in collections intended for conservation is, therefore, estimated to be 1 to 2 million.

Of the 6 million accessions in *ex situ* collections, some 600,000 are maintained within the Consultative Group on International Agricultural Research (CGIAR) system, and the remaining 5.5 million accessions are stored in regional or national genebanks (see Figure 3.1). Table 3.3 provides a regional breakdown of the locations of global *ex situ* accessions. Twelve countries[3] hold more than 45% of the germplasm accessions held in national collections.

*Ex situ* collections consist of seed genebanks, field genebanks and *in vitro* collections. Species with orthodox seeds are stored in seed genebanks, while the latter two methods are used mainly for vegetatively propagated crops and for species with recalcitrant seeds that cannot be dried and stored for long periods under cold conditions (see Annex 1). In addition, perennial species produce small amounts of seed (e.g. some forage species) and species that long life cycles (e.g. trees) are also maintained in this way. Other forms of conservation include cryopreservation and pollen and embryo storage. More details about these methods of storage, which at present are not widely used for routine conservation purposes, are provided in Annex 1-2. It is estimated that, worldwide, 527,000 accessions are stored in field genebanks,[4] while fewer than 38,000 accessions are conserved *in vitro*.[5] Clearly, seed storage is the predominant form of plant genetic resources conservation, accounting for about 90% of the total accessions held *ex situ*.

**Proportions of genebank accessions per type of institution worldwide**

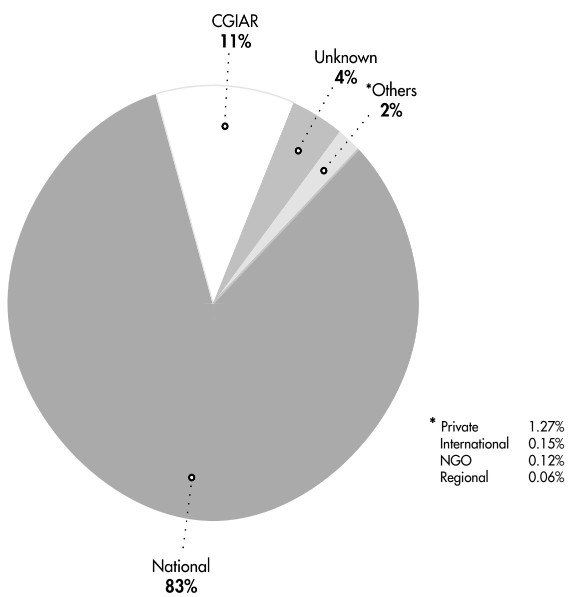



Figure 3.1 *Source:* FAO, WIEWS database

In addition, 698 of the 1,500 botanical gardens worldwide have germplasm collections for the conservation of ornamental species, indigenous crop relatives and medicinal and forest species. Of these, 119 conserve germplasm of cultivated species - including landraces and wild food plants - and other non-cultivated species for local use. Such species are frequently lacking in other *ex situ* germplasm collections. Botanical gardens, therefore, play an important complementary role in *ex situ* conservation systems.

The remainder of this Chapter is divided into sections which survey various aspects of the state of *ex situ* conservation on the basis of information provided by countries during the preparatory process of the International Technical Conference, as well as data maintained in the database of the FAO World Information and Early Warning System. Further information was provided by the institutes and programmes of the Consultative Group on International Agricultural Research (CGIAR). The following aspects are examined:

- past collecting missions and current priorities;
- material conserved in collections by crop species, type (wild relatives, landraces, modern cultivars) and origin, and an assessment of the degree of coverage and remaining gaps;
- storage facilities, including a survey of major genebanks, national capacities for long- and medium-term storage by region, as well as field genebanks and *in vitro* facilities;
- the security of existing collections, including an assessment of duplication and regeneration;
- documentation and characterization;
- germplasm movement;
- the complementary role of botanical gardens.

Finally, a broad assessment of the current state of *ex situ* conservation is made, highlighting the need for rationalization based on the recommendations of the sub-regional preparatory meetings.

## 3.2 COLLECTING

Recognition of the threat posed by genetic erosion led FAO to establish the Panel of Experts on Plant Exploration in 1963. FAO then initiated the massive collecting effort which took place during the 1970s and 1980s. In addition to those carried out by national and bilateral initiatives, many collecting missions were organized by the International Agricultural Research Centres (IARCs). As a result of these efforts, the total number of accessions stored in genebanks increased rapidly (see Section 3.4).

The CGIAR centres have established sizeable germplasm collections of their mandate crops and most of their genetic resource units are now focusing on effective management of existing collections in terms of characterization, evaluation, documentation and regeneration. This trend is illustrated in Figure 3.2 which shows a decreasing trend in the number of accessions collected annually by the CGIAR centres since 1987. Although some further collecting is still recommended by some centres,[6] this is generally directed at filling gaps in existing collections or in response to emergency situations.

**Number of accessions collected by the CGIAR centres**

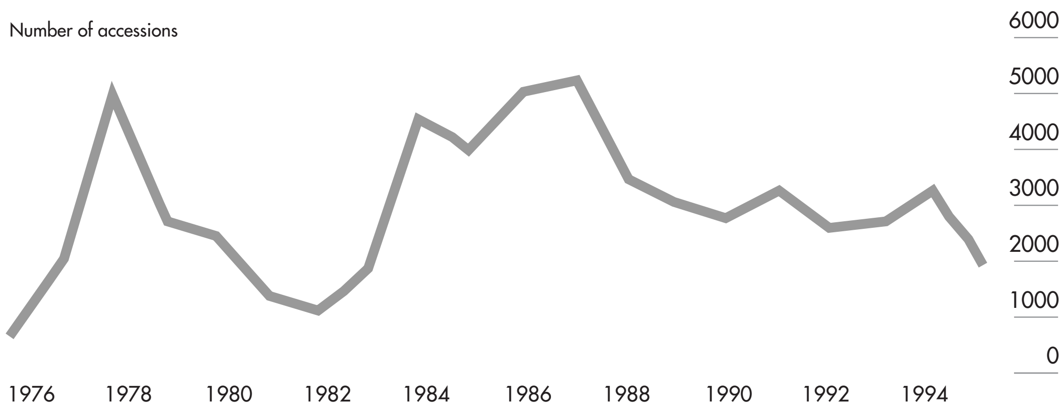



Figure 3.2

*Source:* SGRP Review of the CGIAR Genebank Operations, 1996

The decrease in international collecting activities has developed in parallel with a general improvement in the conservation infrastructure at the national level. With the development of national plant genetic resources programmes and of national conservation facilities, the collecting of germplasm is now becoming more of a country-driven process based on national priorities.[7]

Many countries[8] identify the need for further collecting, with a focus on indigenous landraces, minor crops and other underutilized species, especially crop wild relatives, as many of these remain under-represented in existing collections. A particularly urgent need, identified in a number of sub-regions,[9] is collecting in arid and semi-arid regions.

The need for the integration of conservation strategies, complementing *ex situ* storage with *in situ* conservation, is also recognized. In any case, new collecting activities must be balanced with conservation capacity. Many countries cite the need for further work on inventories and the surveying of indigenous plant diversity in order to determine priority needs in collecting.[10]

### Collecting - the situation at the regional level

**Europe** With the exception of countries within the Mediterranean centre of crop diversity which have been active in collecting indigenous plant genetic resources, few programmes in Western Europe are very active in collecting. Most new germplasm is acquired through introduction and exchange. The international collecting activities of the Royal Botanic Gardens (RBG) at Kew in the United Kingdom, the Centre for Genetic Resources (CGN) of the Netherlands, the National Research Council (CNR) of Italy and the Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK) in Germany are exceptions.

Programmes in Eastern Europe, particularly that of the N. I. Vavilov Institute of Plant Industry (VIR), have a history of national and international collecting and, in the past, acquired large collections of commercially available cultivars. These activities, however, have been severely curtailed by the region's current economic situation and its need to establish priorities for germplasm acquisitions.[11]

**Near East** Because of the importance of the Mediterranean and West Asian regions as centres of diversity, germplasm collecting has been strong since the beginning of the century. Countries in this region pay great attention to collecting and conserving indigenous plant genetic resources, especially of crop species. During the last decade, collecting missions in most countries and territories, except Mauritania, the Libyan Arab Jamahiriya and Palestine, have been frequent and are based on serving national genetic resources and breeding programmes.[12] In the former Soviet Republics of Central Asia however, collecting missions have been infrequent in recent years. Only teams from Turkmenistan and Uzbekistan have collected germplasm regularly.[13]

**Africa** Ethiopia has collected indigenous germplasm extensively. Kenya, through the National Museums of Kenya, has a well-defined strategy for inventory, collection, documentation, propagation and *ex situ* conservation of rare, endangered and endemic species. Other countries in East Africa, however, have major gaps to fill: in particular, Sudan because of its size, diversity and the insecurity in the south; Uganda, due to the lack of conservation facilities and prolonged civil strife; and Eritrea, due to insecurity in the past and the richness of itsplant diversity.[14]

In the Southern Africa sub-region, collecting missions have been carried out in most Southern African Development Community (SADC) countries, either by national research institutions or regional and international organizations such as FAO, the SADC Plant Genetic Resources Centre (SPGRC), IARCs and national NGOs. In general, local missions tend to be multicrop-based and focus on landraces threatened with genetic erosion, while regional and international missions are more crop specific.[15] Some countries, such as Namibia and Malawi, have prepared priority lists of species for collection.[16]

Numerous surveys and collections of germplasm in the region have been carried out by IARCs in Western and Central Africa.[17] National institutes also collect genetic resources of local and introduced germplasm. Breeders are the main prospectors, collectors, and users of plant genetic resources, and priority is given to conserving seeds of major crops and those whose financial importance and area cultivated justify an enhancement programme.

**Asia** India has taken a leading role in collecting germplasm in South Asia with close links to IPGRI's South Asia Regional Office.[18] It is proposed that collecting priorities at the national and regional levels be assigned to wild relatives, endemic species and perennial crops such as fruit.[19]

Countries in East Asia have paid great attention to collecting plant genetic resources, especially crop species.[20] In China, the Ministry of Agriculture has organized annual missions for the last ten years, collecting an average of 3,000 accessions each year. Funding, however, is insufficient to cover all the priority areas. There is also an urgent need to collect genetic resources in an area that is to be flooded by the construction of the Three Gorges Dam in Sichuan Province, an area measuring 54,000 km$^2$. Forty-nine percent of this area's plant species have been classified as rare plants of national priority.[21]

In Japan, six to eight domestic missions are organized annually in addition to five or six international missions.[22] The Republic of Korea's Rural Development Administration (RDA) has made an effort to collect landraces of major crops such as rice, wheat, barley, sorghum, maize and millet since the 1980s. The collecting of wild relatives such as wild soybean and wild rice, as well as endangered crop species, has also been given high priority.[23]

In Southeast Asia, collecting has been carried out mainly in collaboration with the CGIAR centres and other organizations. In Cambodia, the only collecting that has taken place in the last decade has been for rice, carried out jointly by Cambodia, Australia and the International Rice Research Institute (IRRI). The Regional Committee for Southeast Asia (RECSEA) network has promoted collecting activities in the sub-region. In addition, the Asian Vegetable Research and Development Centre (AVRDC) has assisted with the collection of germplasm of sweet potato and various vegetable crops, both indigenous and introduced. Much of the collecting carried out in the sub-region has been crop specific.[24]

**Americas** Collecting in North and Latin America has historically focused on crops which are economically important to countries in the region. Collections of the major food crops such as maize, cassava, potato and sweet potato are, therefore, generally considered to be fairly representative of the available diversity. In recent years, however, germplasm of minor crops and medicinal and ornamental species has also begun to be collected. In many Central American and Caribbean countries, lack of funds is reported to be a major constraint to collecting activities.[25]

Collecting missions are organized regularly in many South American countries.[26] In Brazil, for example, germplasm collecting missions have been carried out throughout the country, especially in areas threatened with habitat destruction by hydroelectric projects, mining, etc. So far, more than 300 expeditions have been carried out and almost 40,000 accessions collected. Further collecting is, however, still required, particularly of materials which show resistance to acidic soils, saline soils and drought.[27]

## 3.3 TYPES OF COLLECTIONS

Collections vary in terms of crop species covered, the extent of the crop gene pool covered, types of accessions (wild relatives, landraces or advanced cultivars) and the origin of material, whether indigenous or exotic.

### 3.3.1 Crop species covered

The most recent 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.[28] Spices, and medicinal, aromatic and ornamental species, together with aquatic plants of relevance for food and agriculture, are rarely found in long-term public collections.

**Contribution of major crop groups to total *ex situ* collections**

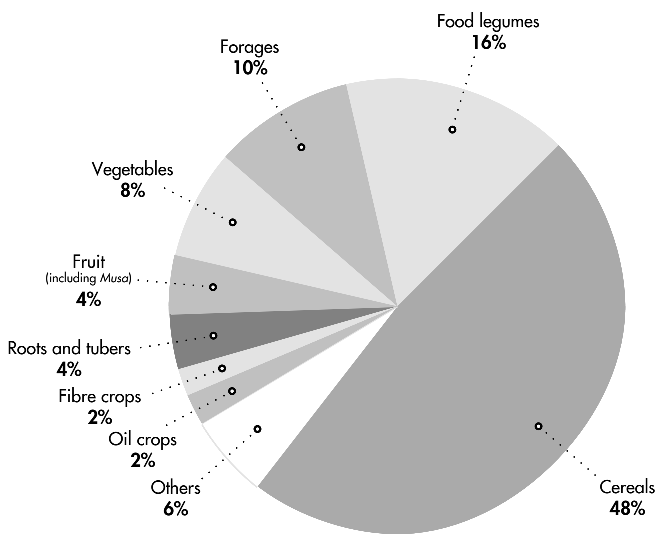



Figure 3.3 *Source:* FAO, WIEWS database

#### Major crops

The diversity of the world's major food crops has generally been well collected, though some specific gaps are known to exist. There are also large variations in the sizes of different collections within this group of crops: wheat accessions number over half a million (14% of total *ex situ* collections); rice accounts for one-third of a million accessions (8%), and maize accessions number one quarter of a million (5%). Cassava, on the other hand, has only 28,000 accessions, or 0.5% of the global total. One explanation for this is that cassava is a bulky, vegetatively propagated plant that is difficult and expensive to conserve.

For wheat, rice, potato, cassava, banana/plantain, sorghum, yam, sweet potato, chickpea, lentil and *Phaseolus,* the largest *ex situ* collections are held by the IARCs. For other crops, however, the largest collections are in national institutions. For example, the All India Coordinated Maize Improvement Programme holds the largest national collection of maize. Plant Gene Resources Canada has the largest collection of barley and China holds the largest collection of soybean. Annex 2 contains more information on the location of collections of major food crops. Collections of other, regionally important crops are distributed in various national genebanks around the world (see Table 3.1 and Appendix 2).

### Minor crops

Some minor crops are poorly represented in *ex situ* collections.[29] For example, worldwide, there are only about 11,500 accessions of all species of yams (0.18% of total accessions) and 3,500 accessions of bambara groundnut (0.05%). Recently, however, some genebanks have begun to accept regional responsibility for long-term storage of some minor crops: rice bean, moth bean and amaranth at NBPGR in India, winged beans at IPB-UPLB in the Philippines and TISTR in Thailand, faba beans at ICARDA in the Syrian Arab Republic, and adzuki beans at NIAR/MAFF, Japan.[30] (See Appendix 2 for full names of organizations cited.)

For many export crops and commodities, large percentages of the global collections are concentrated in a small number of countries. For example, over 80% of oil-palm accessions are in Zaire, while most accessions of rubber are in Malaysia and those of coconut are in Bangladesh.

## Table 3.1 Selected crops: the six largest countries', CGIAR centres' and regional genebanks' holdings of *ex situ* germplasm collections

| Crop | Total world accessions | Major holders 1 | % | 2 | % | 3 | % |
|---|---|---|---|---|---|---|---|
| Wheat | 784,500 | CIMMYT | 13 | United States | 7 | Russia | 6 |
| Barley | 485,000 | Canada | 14 | United States | 11 | United K'dom | 6 |
| Rice | 420,500 | IRRI | 19 | China | 13 | India | 12 |
| Maize | 277,000 | Mexico | 12 | India | 10 | United States | 10 |
| *Phaseolus* | 268,500 | CIAT | 15 | United States | 13 | Mexico | 11 |
| Soybean | 174,500 | China | 15 | United States | 14 | AVRDC | 10 |
| Sorghum | 168,500 | ICRISAT | 21 | United States | 20 | Russian Fed. | 6 |
| *Brassica* | 109,000 | India | 16 | United K'dom | 10 | Germany | 9 |
| Cowpea | 85,500 | IITA | 19 | Philippines | 12 | United States | 11 |
| Groundnut | 81,000 | United States | 27 | India | 20 | ICRISAT | 18 |
| Tomato | 78,000 | United States | 30 | AVRDC | 9 | Philippines | 6 |
| Chickpea | 67,500 | ICRISAT | 26 | ICARDA | 15 | Pakistan | 9 |
| Cotton | 49,000 | India | 34 | France | 13 | Russian Fed. | 12 |
| Sweet potato | 32,000 | CIP | 21 | Japan | 12 | United States | 8 |
| Potato | 31,000 | CIP | 20 | Colombia | 13 | Germany | 13 |
| Faba bean | 29,500 | ICARDA | 33 | Germany | 18 | Italy | 13 |
| Cassava | 28,000 | CIAT | 21 | Brazil | 12 | IITA | 8 |
| Rubber | 27,500 | Malaysia | 76 | Brazil | 6 | Cote d'Ivoire | 5 |
| Lentil | 26,000 | ICARDA | 30 | United States | 10 | Russian Fed. | 8 |
| Garlic/onion | 25,500 | Germany | 18 | United K'dom | 10 | India | 8 |
| Sugarbeet | 24,000 | Germany | 25 | France | 12 | Netherlands | 9 |
| Sugar cane | 23,000 | Brazil | 20 | India | 18 | WICSCBS | 11 |
| Oil palm | 21,000 | Zaire | 83 | Malaysia | 7 | Brazil | 3 |
| Coffee | 21,000 | Cote d'Ivoire | 35 | France | 20 | Cameroon | 7 |
| Yam | 11,500 | IITA | 25 | Cote d'Ivoire | 20 | India | 8 |
| Banana/plantain | 10,500 | INIBAP | 10 | France | 9 | Honduras | 9 |
| Cocoa beans | 9,500 | Brazil | 24 | Trinidad and Tobago | 22 | Venezuela | 17 |
| Taro | 6,000 | Malaysia | 22 | Papua N. Guinea | 13 | India | 11 |
| Coconut | 1,000 | Sierra Leone | 22 | Venezuela | 20 | France | 17 |

*Source:* WIEWS database and SGRP Review of the CGIAR Genebank Operations, 1996

> *(continued)* **Table 3.1 Selected crops: the six largest countries', CGIAR centres' and regional genebanks' holdings of *ex situ* germplasm collections**

| Crop | Total world accessions | Major holders 4 | % | 5 | % | 6 | % |
|---|---|---|---|---|---|---|---|
| Wheat | 784,500 | India | 6 | Germany | 6 | Italy | 5 |
| Barley | 485,000 | ICARDA | 5 | Brazil | 5 | Russian Fed. | 5 |
| Rice | 420,500 | United States | 8 | Japan | 5 | WARDA | 4 |
| Maize | 277,000 | Russian Fed. | 7 | CIMMYT | 5 | Colombia | 4 |
| *Phaseolus* | 268,500 | Brazil | 10 | Germany | 3 | Russian Fed. | 3 |
| Soybean | 174,500 | Brazil | 5 | Ukraine | 4 | Russian Fed. | 3 |
| Sorghum | 168,500 | Brazil | 6 | Ethiopia | 4 | Australia | 4 |
| *Brassica* | 109,000 | United States | 8 | China | 6 | Rep. of Korea | 3 |
| Cowpea | 85,500 | AVRDC | 7 | India | 6 | Indonesia | 5 |
| Groundnut | 81,000 | China | 8 | Argentina | 6 | Zambia | 2 |
| Tomato | 78,000 | Russian Fed. | 4 | Germany | 4 | Colombia | 3 |
| Chickpea | 67,500 | United States | 9 | Islam. Repub. of Iran | 8 | Russian Fed. | 4 |
| Cotton | 49,000 | United States | 6 | Pakistan | 5 | China | 3 |
| Sweet potato | 32,000 | Peru | 6 | Philippines | 5 | (several) | 4 |
| Potato | 31,000 | United States | 8 | Argentina | 4 | Czech Repub. | 4 |
| Faba bean | 29,500 | Spain | 6 | Russian Fed. | 6 | France | 6 |
| Cassava | 28,000 | Uganda | 6 | India | 5 | Malawi | 4 |
| Rubber | 27,500 | Liberia | 4 | Viet Nam | 4 | Indonesia | 2 |
| Lentil | 26,000 | Islam. Repub. of Iran | 7 | Pakistan | 4 | India | 3 |
| Garlic/onion | 25,500 | Russian Fed. | 5 | Hungary | 6 | France | 4 |
| Sugarbeet | 24,000 | Yugoslavia | 9 | Russian Fed. | 7 | Japan | 5 |
| Sugar cane | 23,000 | United States | 9 | Dominican Rep. | 9 | Cuba | 6 |
| Oil palm | 21,000 | Ecuador | 1 | Colombia | 1 | Indonesia | 1 |
| Coffee | 21,000 | Costa Rica | 7 | Ethiopia | 6 | Colombia | 5 |
| Yam | 11,500 | Philippines | 5 | Sri Lanka | 4 | Solomon Is. | 4 |
| Banana/plantain | 10,500 | Philippines | 6 | Papua N. Guinea | 5 | Cameroon | 5 |
| Cocoa beans | 9,500 | France | 7 | Costa Rica | 6 | Colombia | 5 |
| Taro | 6,000 | United States | 8 | Indonesia | 7 | Philippines | 6 |
| Coconut | 1,000 | India | 13 | Colombia | 11 | Philippines | 9 |

Source: WIEWS database and SGRP Review of the CGIAR Genebank Operations, 1996

### 3.3.2 Types of material stored

According to the WIEWS database, about half of all *ex situ* accessions (48%) for which the type of material is known are advanced cultivars or breeders' lines, while just over a third are landraces or old cultivars, and about 15% are wild or weedy plants or crop relatives. These estimates, however, are subject to wide error as the type of accession is only known definitively for a third of all accessions, and no information at all is available for half of all accessions.[31] (Appendix 2 provides further information about collections on a crop by crop basis.) Figure 3.4 illustrates differences in the constitution of different types of collections.

**Types of accessions in *ex situ* collections**

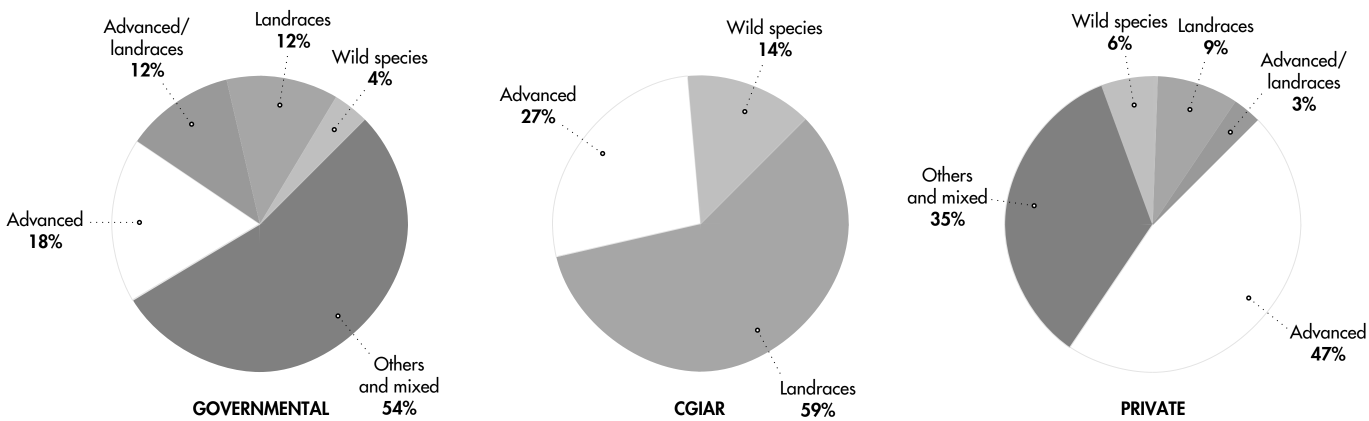



Figure 3.4 *Source:* FAO, WIEWS database

More complete data are available on the base collections in CGIAR genebanks. Overall, CGIAR base collections contain 59% landraces and old cultivars, 14% wild and weedy relatives and 27% advanced cultivars and breeders' lines. However, these aggregate figures differ widely from centre to centre as well as for different crops held in the same centre. For example, CIMMYT's wheat collection contains more than 50% advanced cultivars and breeding lines, but the maize collection contains almost exclusively landraces, old cultivars and wild and weedy relatives.

In private collections, advanced cultivars are more important, making up 75% of accessions for which the type is known, while landraces account for only 15% and wild species 10% of accessions.

The situation in national collections explains the situation worldwide, as national genebanks hold more than 80% of total collections.

Approximately half the accessions for which the type of material is known are advanced cultivars and breeding lines, while a third are landraces and about 10% are wild species.

### 3.3.3 Sources of material in genebanks

The Convention on Biological Diversity emphasizes in-country conservation of indigenous genetic resources *in situ* and *ex situ*. Some countries are now consolidating national collections which represent available indigenous diversity and include other diversity of potential importance to the country.[32] According to some European programmes, giving priority to long-term conservation needs, as emphasized in the Convention, might imply weakening of the links with breeders.[33] This may particularly be the case when breeders' collections are transferred to central national genebanks.

Quantitative estimates of the proportion of indigenous accessions in national collections were provided by 24 countries (see Table 3.2). More general information on the origin of genebank accessions was provided by 40 countries and can be summarized as follows:

**Europe** The situation varies greatly from country to country. Traditionally, collections were assembled to serve national plant breeding needs and included introduced and local material, advanced and old cultivars, breeding lines and special genetic stocks and, to a lesser extent, indigenous and foreign landraces and wild species of crops important to European agriculture. Indigenous genetic resources have, however, received special attention in the collections of countries in the Mediterranean and Near Eastern centres of crop diversity, such as Greece, Israel, Italy and Turkey. Others, notably France, hold collections of tropical crops.

**Near East** The majority of accessions in national genebanks is of local origin.

**Africa** National genebanks contain mostly local material. Introduced material is often maintained in working collections as, for example, in South Africa and Zimbabwe.

**Table 3.2 Percentage of indigenous accessions in national genebanks**

| Country | Percentage |
|---|---|
| **Europe** | |
| Bulgaria | 12 |
| Czech Republic | 16 |
| Republic of Moldova | 40 |
| Romania | 71 |
| Slovakia | 8 |
| Belgium | 75 |
| **Africa** | |
| Cameroon (roots and tubers) | 75 |
| Cameroon (fruits) | 25 |
| Ethiopia | 100 |
| Mauritius | 100 |
| Angola | 100 |
| Malawi | 100 |
| Namibia | 100 |
| Senegal | 10 |
| **Near East** | |
| Islamic Republic of Iran | >95 |
| Cyprus | 100 |
| Iraq | 22 |
| **Americas** | |
| Brazil | 24 |
| Colombia | 55 |
| Ecuador | 52 |
| United States | 19 |
| **Asia** | |
| China | 85 |
| Democratic People's Republic of Korea | 20 |
| Republic of Korea | 18 |
| Sri Lanka | 67 |

*Source*: 24 Country Reports

**Asia and the Pacific**

Most accessions in South and Southeast Asia were obtained locally, including 85% of China's accessions. The exceptions are the Republic of Korea and the Democratic People's Republic of Korea where the majority of accessions are introduced. No information was available for Japan or India. In Australia and New Zealand, almost all accessions are imported.

**Americas**

In Colombia and Ecuador, approximately half of all accessions are local and half are imported. One fifth of accessions in the United States were obtained locally.

Information on the origin of accessions is more complete for the collections held in the International Agricultural Research Centres.[34] Most (65%) of ICARDA's collections of food legumes, cereals and forage crops originate in West Asia and North Africa, the regions where this Centre's activities are focused. Similarly, Central and West Africa are the main sources of accessions for IITA's collection of rice (72%), yam (99%) and cassava (85%). Around half of the cowpea, wild *Vigna* and bambara groundnut collections also originate in these regions, although East and Southern Africa are also important sources for these crops.

Most of IRRI's rice collection (*Oryza sativa* and wild relatives) originates in tropical Asia, with India providing 20% of the accessions. West Africa is the source of 94% of WARDA's collection of *O. glaberrima* and 72% of *O. sativa,* with Madagascar supplying 26%. South America is the main source of the potato (*Solanum* sp.) collection at CIP, with Bolivia and Peru accounting for 60% of the collection. South America is also the main source of wild relatives of sweet potato (*Ipomoea* spp.). Landraces of the crop itself (*Ipomoea batatas*) have been obtained from other parts of the world as well.

### 3.3.4 Coverage of collections and remaining gaps

As there has never been a comprehensive inventory of PGRFA (wild or domesticated, *in situ* or *ex situ*), it is impossible to say how representative current *ex situ* collections are of total diversity. Collections of cereal landraces are, however, probably more "complete" than those of pulses, most root crops, and fruit and vegetables (with the possible exceptions of potato and tomato).[35] Coverage of wild relatives is generally acknowledged to be very limited and inconsistent, while coverage of many forest and forage species is minimal. The extent of the coverage of selected major crops and crop commodities is analysed in more detail11in Annex 2.

Worldwide, there are known to be gaps in the collections of minor crops and underutilized species, particularly in the coverage of landraces and wild relatives from their centres of diversity and cultivation. Gaps have also been noted in the documentation of knowledge about useful characteristics and the diversity of many neglected species. Targeted collecting of selected species and assessments of the genetic diversity of landraces are, therefore, priorities. On-farm conservation may be a useful complement to field genebanks and *in vitro* collections for many of these crops.[36]

**Table 3.3 Genebanks and accessions in *ex situ* collections, by region**

| Region | Accessions | | Genebanks | |
|---|---|---|---|---|
| | Number | % | Number | % |
| Africa | 353,523 | 6 | 124 | 10 |
| Latin America, the 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 |
| **Total** | **5,554,505** | **100** | **1,308** | **100** |
| **CGIAR Total** | **593,191** | | **12** | |

*Source*: Country Reports and WIEWS database

A large number of countries in their reports pointed to the lack of knowledge of indigenous plant genetic resources and the need for surveys, inventories, taxonomic studies and other analyses of existing diversity.[37] Filling identified gaps in existing collections and adding new species to collections, such as underutilized crops, ornamentals, spices and aromatic, medicinal and forage species, etc., requires good inventories as these are important tools for planning and prioritizing collecting and other conservation activities. Inventories can also help pinpoint sites where collecting would be most worthwhile.(See Chapter Two, section 2.2).

## 3.4 STORAGE FACILITIES

The number of storage facilities has increased dramatically over the past two decades. One of the earliest *ex situ* germplasm collections was started by N.I. Vavilov in the former Soviet Union before World War II. The establishment of other national collections followed: the United States (1958), Ghana (1964), Japan (1966), Canada (1970), Germany (1970), Italy (1970), Poland (1971), Turkey (1972), Brazil (1974) and Ethiopia (1976). By the end of the 1970s, there were about 54 seed stores of which 24 had long-term capacities, as well as a number of working collections. Today, besides the genebanks of the IARCs, there are over 1,300 national and regional germplasm collections, of which 397 are maintained under long- or medium-term storage conditions.

Many countries, in fact, have more than one *ex situ* facility or collection, although in many cases these may be used as active or research collections. For example, India has 70 collections. The type and constitution of these collections vary according to the aims of the conservation programme. Many of the collections are

Table 3.4 ***Ex situ* storage facilities and the regeneration situation in the world's largest national base collections**

| Country and institute | Accessions | Facilities | Regeneration status |
|---|---|---|---|
| China<br>Institute of Crop Germplasm | 300,000 | Long-term storage, space available | Not yet needed since genebank is only eight years old |
| United States<br>National Seed Storage Laboratory | 268,000 | Long-term storage, capacity of 1 million accessions | 19% requires regeneration; main constraints are lack of human resources and facilities for regenerating cross-pollinated crops |
| Russian Fed.<br>VIR | 177,680 | No long-term facilities | Regeneration required frequently |
| Japan<br>NIAR | 146,091 | Long-term facilities | 4% requires regeneration; no specific problems reported |
| India<br>NBPGR | 144,109 | New genebank being built for 600,000 accessions | 63% requires regeneration; no specific problems reported |
| Republic of Korea<br>RDA | 115,639 | Long-term facilities, total capacity 200,000 accessions | 50% requires regeneration; main problems are with cross-pollinated species |
| Canada<br>PGRC | 100,000 | Long-term facilities | No specific problems reported |
| Germany<br>IPK (Institute for Plant Genetics and Crop Plant Research), Gatersleben | 103,000 | Long-term facilities | Main constraint is lack of staff resources |
| Brazil<br>CENARGEN | 60,000 | Long-term facilities, capacity for 100,000 accessions | 64% requires regeneration; main constraints are funds, infrastructure and human resources |
| Germany<br>FAL, Braunschweig | 57,000 | Long-term facilities | Main constraint is lack of staff resources |
| Italy<br>Bari | 55,806 | Long-term facilities | No specific problems reported |
| Ethiopia<br>Biodiversity Institute | 54,000 | Long-term facilities | 8% requires regeneration; main constraints are lack of funds, land and human resources |
| Hungary<br>Institute for Agrobotany | 45,833 | Long-term facilities | 40% requires regeneration; no specific problems reported |

> *(continued)* **Table 3.4** ***Ex situ* storage facilities and the regeneration situation in the world's largest national base collections**

| Country and institute | Accessions | Facilities | Regeneration status |
|---|---|---|---|
| Poland Plant Breeding and Acclimatization Institute | 44,883 | Long-term facilities | 3% requires regeneration; no specific problems reported |
| Philippines NPGRL | 32,446 | Long-term facilities | No specific problems reported |

*Source*: Country Reports

breeders' or working collections, and conservation is likely to be short-term. Of the 1,308 genebanks registered in the WIEWS database, 495 (38%) are located in Europe, 327 (25%) in the Americas, and 292 (22%) are located in Asia (see Table 3.3). The fifteen largest national base collections together hold approximately 1.6 million accessions, or 33% of the total national seed collections (see Table 3.4). There are also some large active germplasm collections, one notable example is the National Small Grains Collection in the United States which holds 119,000 accessions. Most genebanks are seed stores, but there are also many field collections. These are particularly important among the small island developing states.

### 3.4.1 Long-, medium- and short-term seed genebank facilities

A total of 75 countries report that they have seed storage facilities suitable for medium- to long-term storage, but many also report problems in maintaining equipment, lack of suitable drying facilities and unreliable electricity supplies, all major constraints to reliable seed storage.

Based on the information provided in the Country Reports, 35 of these countries have secure, long-term seed storage facilities, as per the following three criteria:

- seeds are maintained according to the preferred international standards for long-term storage;
- the facilities are known to have long-term storage capacities and reliable power supplies;
- procedures for safe duplication and regeneration are in place.[38]

These countries include 15 in Europe, seven in the Americas, five in Asia, and four in each of Africa and the Near East regions (see Figure 3.6 and Appendix 1).

In addition, nine of the CGIAR genebanks and four of the regional genebanks offer secure, long-term facilities (see Table 3.5 and Table 3.6). It is notable that one of the world's largest genebanks, the VIR in the Russian Federation, does not meet these requirements.

A further 56 countries report having facilities suitable for medium- to short-term storage only. Field genebanks exist in at least 103 countries; 63 countries report having *in vitro* conservation capacity.

According to information from the WIEWS database, only about 60% of accessions are known to be stored in medium- or long-term facilities (see Figure 3.5). A further 8% are stored in short-term conditions and about 10% are stored in field genebanks, *in vitro* or under cryopreservation. It should be noted that further information is required in order to distinguish between long-term and medium-term storage conditions for many accessions, and that no information at all is available for 25% of accessions. (Appendix 2 provides information on storage conditions in various institutions on a crop by crop basis.)

**Percentage of *ex situ* collections by storage type**

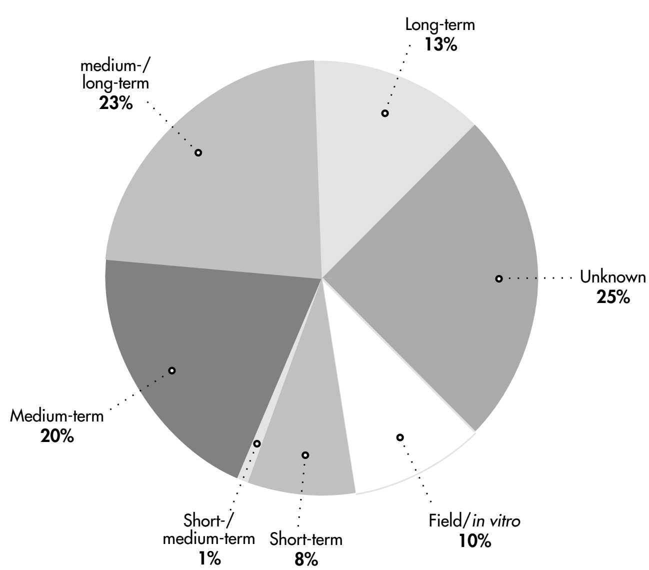



Figure 3.5 *Source:* FAO, WIEWS database

## Review of genebank facilities by region

The following assessment, which draws largely on information provided in Country Reports, shows that conditions in genebanks vary widely between continents. Each region has genebanks which operate at very high standards. For each such facility, however, there are many others that may be incapable, at present, of performing the basic conservation role of a genebank.

**Europe** Most European countries generally have well-established genebanks that meet international standards. Albania and newly independent states such as the Baltic countries and Belarus, Ukraine, etc., are putting the necessary facilities into place. In some countries national genebanks hold the country's base collections for all or a large range of crops (for example, in Greece, the Netherlands, Portugal, Spain and most countries in Eastern Europe). In addition, the Nordic Gene Bank (NGB) holds the base collections for the five Nordic countries. In other countries such as Austria, France, Switzerland and the United Kingdom, genebanks are specialized with mandates for the conservation of particular crops or groups of crops. The VIR in the Russian Federation and some of the other programmes in Eastern Europe regularly regenerate their collections because long-term storage facilities are not available.

**Near East** Apart from Israel, few countries in the South and East Mediterranean[39] have long-term storage facilities. Egypt's facilities have limited capacities and, in Morocco, only forage and pasture species (10,187 accessions) are stored under long-term conditions (-18°C). Accessions of other species in these countries are stored in active collections in a range of institutions. Both countries propose to create national genebanks. In other countries in the sub-region, such as Algeria, Jordan, Lebanon and Mauritania, and in the territory of Palestine, even medium-term storage facilities are lacking. In the remaining countries — Cyprus, Egypt, Morocco, the Syrian Arab Republic and Tunisia — efforts have been made by various institutions during the last decade to build medium-term storage facilities for the conservation of national collections, though these do not always work properly due to maintenance problems.

Conservation facilities in West Asia[40] vary widely from one country to another. Turkey has the most advanced conservation facilities allowing for both long- and short-term conservation. National collections in Iraq and Yemen are kept as active collections. In the other countries, *ex situ* conservation activities are either lacking or just in the process of being developed. Pakistan and the Islamic Republic of Iran have good long-term facilities, but none of the other countries in Central Asia have adequate storage facilities. Collections are generally maintained as active collections and regeneration is carried out frequently to maintain seed viability.

**Africa** In East Africa, Kenya and Ethiopia have by far the most advanced conservation facilities with well-defined and efficiently run programmes. Historically, Ethiopia's programme has benefitted from well-trained and dedicated national staff. Bilateral (financial and technical) funding from the German Ministry for Economic Cooperation and Development (BMZ) handled through GTZ, has helped provide both countries with well-developed genebanks and well-equipped

**Status of national *ex situ* collections**

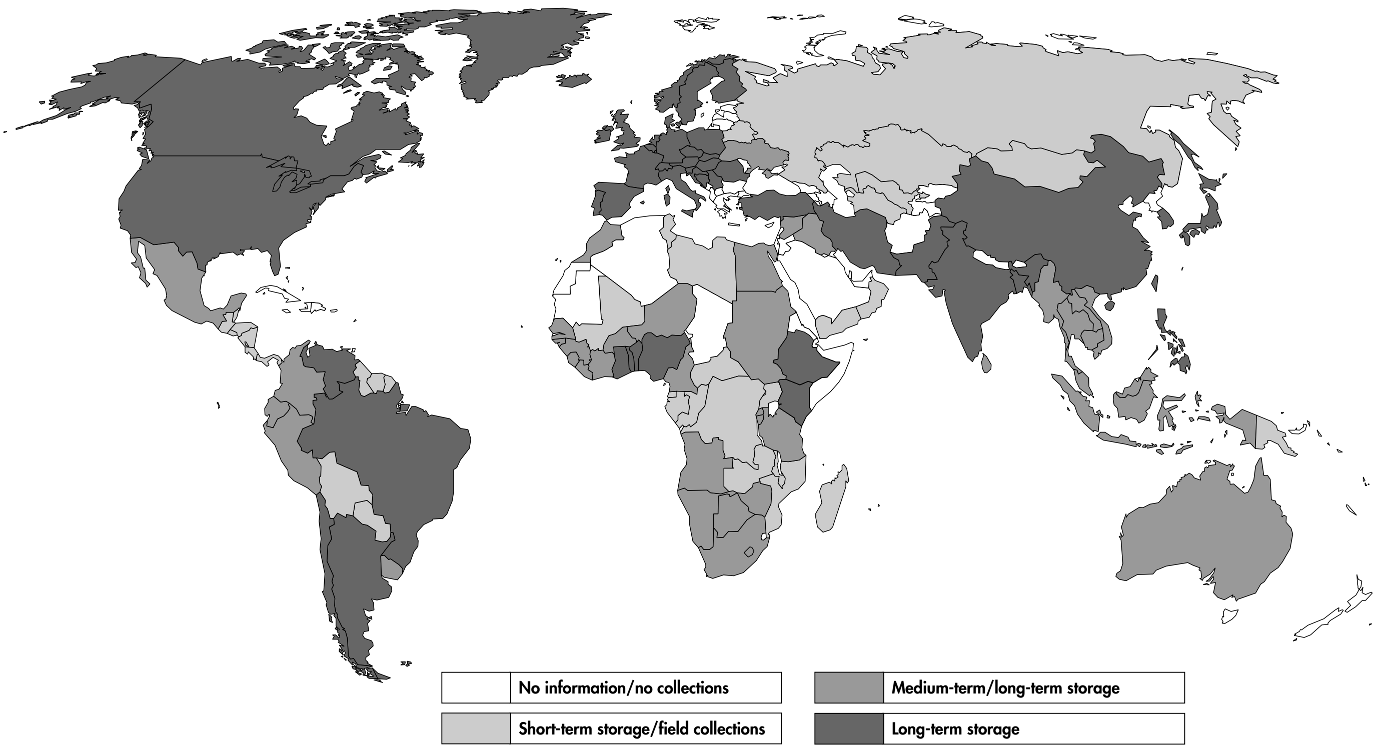



Figure 3.6

*Source:* WIEWS database and Country Reports

laboratories. Both genebanks have the potential to undertake more responsibilities for both world and regional base collections.[41] The Sudan uses freezers for long-term storage but the conservation programme suffers from lack of personnel. Other countries in the sub-region have either minimal or no seed storage facilities.

Storage facilities in the Indian Ocean Island states are generally poor. Madagascar has a cold room funded by the United States Agency for International Development, but it does not operate at the required temperature, and freezers donated by IPGRI and IRRI suffer from unreliable power supplies. Seed drying poses an additional problem. Mauritius has a small facility for seed storage but is constrained by the lack of trained staff.[42]

In West Africa, Nigeria and Côte d'Ivoire have long-term storage facilities with refrigerated chambers, while Benin, the Niger, Ghana, Guinea and Senegal have functioning genebanks using freezers.[43] In general, freezers rather than cool chambers have proved more appropriate for long-term conservation in the sub-region as the latter are more difficult to maintain and repair.[44] A further constraint to seed storage is the lack of seed-drying facilities. This is a particular problem in the coastal regions where relative humidity averages between 60% and 90%.[45]

In Southern Africa, most countries have set up national plant genetic resources centres and seed storage facilities under the SADC Plant Genetic Resources Centre (SPGRC) project. Genebank infrastructure and facilities in the region vary. Countries covered by the SPGRC project have typically received five freezers. Namibia and Botswana, for example, have recently constructed new genebanks which are well equipped for seed storage, and such a facility is being constructed in Zimbabwe; South Africa and, for now, Zimbabwe do not have national genebanks but collections are well maintained by several research organizations. Seed dryers were recently supplied by SPGRC. Erratic power supply is a further major problem in maintaining seed collections in the region; more than half of the national facilities lack a standby generator.[46]

**Asia** In South Asia, the only country with a reliable long-term seed storage facility is India, which has a large base collection of 144,000 accessions. The total capacity of the facility is over 500,000 accessions. Bangladesh has long-term storage facilities which serve as the global repository for jute and allied fibres, but this facility suffers from maintenance problems and lack of seed-drying equipment. Sri Lanka has a good facility for medium-term storage with a capacity to hold 25,000 accessions at 1°C. Storage facilities in the remainder of the countries in the sub-region are generally poor.[47]

In East Asia, China, Japan and the Republic of Korea have base collections containing about 560,000 accessions which are stored and managed according to international recommendations for long-term storage. In addition, there are many active collections responsible for germplasm regeneration, characterization, distribution and utilization which are maintained in medium-term genebanks in the provinces by professional research institutes, universities and experimental stations.

In Southeast Asia and the Pacific,[48] long-term storage facilities exist in the Philippines, Malaysia, Thailand and Indonesia. The National Plant Genetics Resources Laboratory (NPGRL) in the Philippines holds the world base collection of *Luffa, Psophocarpus tetragonolobus, Momordica* and *Trichosanthes*, the duplicate world collection of *Vigna radiata*, the duplicate Asian collection of *Lycopersicon,* and the Southeast Asian collection of indigenous vegetables as well as the Philippines' national base collection. Medium-term storage facilities are available in Viet Nam.

Papua New Guinea, like the other Pacific Island States, does not have a long-term seed store. Vegetatively-propagated crops dominate the agricultural sector in these countries and most germplasm conservation is, therefore, in field genebanks.

**Americas** The capacity of *ex situ* conservation programmes varies throughout South America.[49] Argentina, Brazil, Chile and Venezuela have reliable long-term storage facilities, while Ecuador stores seed at -7°C. Other countries have no facilities for long-term storage and most countries have problems with seed-drying prior to storage. Many countries also have collections maintained by breeders as working collections.

In Central America and Mexico, national seed storage facilities are generally inadequate. Long- and medium-term seed storage facilities are available in Costa Rica, El Salvador,[50] Mexico and Nicaragua, but problems with equipment maintenance and funding are common. Inventories carried out by the Latin American Maize Project (LAMP) have revealed that, due to poor storage conditions, much of the maize germplasm stored in the region has lost its viability (see Chapter Six).[51]

Cuba is the only country in the Caribbean with a long-term seed storage facility.[52] All the other Caribbean Island States have, at the most, limited facilities for short-term seed storage. As the main species conserved are vegetatively propagated (sweet potato, yam, cassava, *Musa* etc.), conservation activities focus on field or *in vitro* germplasm collections. One exception is sugar cane seed storage at the West Indies Central Sugar Cane Breeding Station in Barbados.

The United States and Canada have base collections holding a total of 368,000 accessions in long-term storage, meeting international standards. Both countries also have many institutions with active or working collections of germplasm stored under medium- or short-term conditions.

## Regional and international genebanks

Regional and international centres have important germplasm collections and most have secure long-term storage facilities which meet international standards. However, it is notable that neither the West Africa Rice Development Association (WARDA) nor the International Center for Research in Agroforestry (ICRAF) have long-term storage facilities; WARDA's base collection is maintained at IITA, while new facilities are under construction at ICRAF. The urgent need to speed up the International Crops Research Institute for the Semi-Arid Tropics' (ICRISAT) transfer of accessions to long-term storage was recently highlighted in an external review of the CGIAR genebanks.[53] A new building for storing wheat and maize accessions is to be constructed at CIMMYT. Several centres are aware that shortage of storage space could create problems in the medium to long term. Table 3.5 lists regional genebanks, while Table 3.6 gives details of international genebanks.

**Table 3.5 *Ex situ* storage facilities and main crops conserved in regional genebanks**

| Genebank | Year established | Accessions | Storage facilities[1] | Regeneration status |
|---|---|---|---|---|
| Tropical Agricultural Research and Training Centre (CATIE), Costa Rica | 1976 | 35,056 | LT, MT, IV, F | Cucurbita; *Capsicum*; *Phaseolus;* coffee; cocoa |
| Asian Vegetable Research and Development Centre (AVRDC), Taiwan, China | 1971 | 37,618 | LT, MT, F, IV | Tomato; *Capsicum*; soybean; mung bean |
| Nordic Gene Bank (NGB), Sweden | 1979 | 27,303 | LT, MT, F, IV | Cereals; fruits and berries; forage crops; potatoes; vegetables; root crops, oil crops and pulses. |
| Southern African Development Community-Plant Genetic Resources Centre (SPGRC), Zambia | 1989 | 5,054 | LT | Base collections; duplicates of national collections |
| Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD), the Syrian Arab Rep. | 1971 | | F | Fruit trees |

[1] LT = long-term, MT = medium-term, IV = *in vitro*, F = field

*Source:* FAO, WIEWS database

## 3.4.2 Field genebanks and *in vitro* facilities

Plant species that are vegetatively propagated, that have long life cycles or produce short-lived (recalcitrant) seed, are commonly maintained in field genebanks. These include crops such as cassava, potato, banana, plantain, yam and tree crops such as fruits, coffee, cocoa and coconut which are normally grown in orchards and plantations.

The need to improve and develop appropriate conservation technologies for species with non-orthodox seeds and for vegetatively propagated plants has been reported by many countries.[54] In response to this need, an Expert Consultation on the Management of Field and *In Vitro* Genebanks was held in Colombia in 1996. FAO, CGIAR's System-wide Genetic Resources Programme (SGRP), IPGRI and CIAT sponsored this consultative meeting which examined the role of field and *in vitro* genebanks and their strategies to conserve and use vegetatively propagated crops. Further, problems and constraints were examined in order to develop management guidelines for these genebanks.

**Table 3.6 *Ex situ* storage facilities and extent of duplication in CGIAR centres**

| Centre | Number of accessions | Storage facilities' | LT storage' capacity (accessions) | Duplication | % |
|---|---|---|---|---|---|
| ICRISAT | 110,478 | LT, MT, ST, IV | 96,500 | Chickpea<br>Millet<br>Pigeon pea<br>Groundnut<br>Sorghum | 98<br>24<br>22<br>28<br>42 |
| CIAT | 70,940 | LT, MT, ST, IV, F | 100,000 | *Phaseolus*<br>Cassava | 79<br>90 |
| CIMMYT | 136,637 | LT, MT, F | 108,000* | Wheat<br>Maize | 50<br>80 |
| CIP | 13,911 | LT, MT, IV, F, Cr | 10,000 | Potato<br>Sweet potato | 100<br>93 |
| ICARDA | 109,029 | LT, MT, ST, F | 70,000 | Durum wheat<br>Faba bean<br>Lentil<br>Chickpea<br>Barley | 41<br>35<br>91<br>51<br>23 |
| ICRAF | (Data not available) | LT**, MT**, F | 4 freezers** | | |
| IITA | 39,765 | LT, MT, IV, F | 60-70,000 | Cowpea<br>Soybean<br>Yam<br>Bambara groundnut<br>*Musa* sp.<br>Cassava<br>Rice | 30<br>47<br>20<br>17<br>89<br>26<br>42 |
| ILRI | 13,470 | LT, MT, IV, F | 13,000 | Forage grasses and legumes | 74 |
| IRRI | 80,646 | LT, MT | 108,060 | *Oryza sativa*<br>*O. glaberrima*<br>Rice wild sp. | 77<br>54<br>65 |
| WARDA | 17,440 | ST | 20,000** | *O. sativa* (at IRRI)<br>*O. sativa* (at IITA)<br>*O. glaberrima* (IITA) | 90<br>39<br>80 |
| INIBAP/ IPGRI | 1,051 | IV, Cr, F | | Banana/plantain | 39 |
| **Total** | **593,367** | | | | |

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

*Source*: SGRP[55] Review of the CGIAR Genebank Operations, 1996

### Field genebanks

Most countries have at least one field genebank and many countries have several. Although plants in field genebanks can be readily characterized and evaluated, they are also susceptible to loss, due either to pest or disease attack or adverse environmental conditions such as drought, floods, fire, wind, etc. The maintenance of field genebanks is both labour-intensive and costly, particularly for vegetatively propagated crops which require regular replanting and whose long-term security is uncertain. A further constraint of field genebanks is that they must be located in areas which are geographically and environmentally appropriate for the crop species. Approximately 527,000 accessions are stored worldwide in field genebanks. On a regional basis, the following information is available:[56]

**Europe** Approximately 284,000 accessions[57] are stored in field genebanks. Most of these collections consist of fruit trees and berries, but other crops such as potato, vines and hops are also maintained in this way.

**Near East** Field genebanks are used especially to maintain collections of fruits, nuts, olives, garlic and onions. Approximately 10,000 accessions[58] are stored in field genebanks in this region. Turkey reports 12 field genebanks at various institutions for fruit trees. Some countries, including Turkey, report a lack of funds for maintaining collections.

**Asia and the Pacific** Field genebanks in the region contain approximately 84,000 accessions,[59] of which 34,000 are in China.[60] In the Pacific Islands, field genebanks are the most common form of germplasm conservation, and are used for most major crops, including sweet potato, yam, taro, banana and plantain, cocoa and coconut. Papua New Guinea reports difficulty in maintaining field genebanks due to pest and disease attack, adverse environmental effects and lack of funding. Field collection losses include taro and yam collections in the Solomon Islands, taro in Tonga, and taro and yams in Western Samoa.[61]

Field genebanks are important in all countries in South and Southeast Asia. Bangladesh and Nepal report problems in maintaining collections due to lack of funding.[62]

**Africa** Approximately 16,000 accessions[63] are maintained in field genebanks which exist in almost every country in the region. In Eritrea, genebanks are still in the developmental stage. The current status of the coffee genebanks in Angola is unknown as they are located in areas affected by the war there. Mauritius reports the loss of its banana genebank as a result of a cyclone in 1994; the Seychelles reports that land availability is a limiting factor.

**Americas** Field genebanks are the only form of *ex situ* conservation in several of the Caribbean countries, where they are used for the conservation of sweet potato, yam, pineapple, cocoa, etc. Hurricanes have been responsible for major losses in recent years: a field collection of yams was lost in Saint Lucia in 1994 and Guadeloupe's banana collection was decimated in the late 1980s. In the remainder of the region, approximately 117,000 accessions[64] are maintained in field collections; the largest collections are in Canada (30,519 accessions), Brazil (24,263) and the United State (21,574).

### *In vitro* facilities

*In vitro* storage is now being developed as an alternative or complementary method for conserving vegetatively propagated crops as well as those with long life-cycles and those with recalcitrant seeds. The relative advantages of *in vitro* collections are the possibility of storing and distributing disease-free material (see Annex 1), storage in controlled environments without risk of natural disaster, and the possibility of rapidly multiplying material when required for use.

*In vitro* storage methods have, however, been developed for only a relatively small number of species and the technology requires expensive equipment and skilled staff. The number of *in vitro* laboratories being used for the conservation of genetic resources worldwide is, therefore, small. Sixty-three countries report having a tissue culture facility, but it is unlikely that these facilities are all being used for conservation purposes. The total number of accessions stored *in vitro* is approximately 38,000.[65] In the IARCs, tissue culture facilities are available in those centres responsible for crops which are usually clonally propagated, including CIAT (cassava), CIP (potato, sweet potato and Andean root and tuber crops), IITA (yam, cassava, banana/plantain and cocoyam), ILRI (grasses) and INIBAP (banana/plantain). At CIAT, steps are being taken to increase *in vitro* storage capacity.

**Africa** At the national level, *in vitro* laboratories are reported to exist in 10 countries,[66] four of which — Kenya, Côte d'Ivoire, Ghana and Togo — have requested assistance to improve their facilities. A further three countries — Lesotho, Malawi and the Niger — stated that they are interested in developing *in vitro* laboratories. However, *in vitro* methods are rarely used for conservation in the region.[67] Existing facilities, are being used predominantly as propagation units to supply planting material to the farming community.

**Asia** Eleven countries report having *in vitro* laboratories. There vary from sophisticated and well-equipped facilities - India, China and the Philippines - to very basic laboratories - Nepal and Papua New Guinea. In Western Samoa, the *in vitro* laboratory is used as a Pacific region centre for the storage and distribution of germplasm of sweet potato, taro, banana, vanilla, cassava and yam.

**Near East** Only six countries are reported to have *in vitro* facilities: Pakistan, Israel, Jordan, Egypt, Iraq and Turkey. The Syrian Arab Republic has requested assistance to develop a biotechnology laboratory, while some *in vitro* conservation studies have been conducted on almond, wild pear, apple and potato at the Jordan University of Science and Technology.

**Europe** Most countries in Western Europe and many in Eastern Europe have *in vitro* laboratories. In northern European countries, these are frequently used for the storage of potato and *Allium* germplasm. Lithuania, Denmark, Greece and Ireland have expressed the need for improved facilities.

**Americas** Twenty-four countries, 71% of those submitting Country Reports, report *in vitro* facilities. In the United States, *in vitro* collections of sweet potato, *Corylus,* strawberry, hop, mint, pear and various berries are maintained by the United States Department of Agriculture. In Colombia, sugar cane, *Solanum* spp., sweet potato and *Musa* collections are maintained *in vitro,* and, in Brazil, *in vitro* collections contain 2,221 accessions of cassava, sweet potato, potato, yam, asparagus, *Stevia,* strawberry and banana. In the Caribbean, *in vitro* laboratories are used more as production facilities than for germplasm storage, though sweet potato, yam and cassava germplasm are stored in a regional laboratory in Barbados. Cuba is also developing *in vitro* storage protocols for a number of crops.

## 3.5 SECURITY OF STORED MATERIAL

### 3.5.1 State of duplication

Safety duplication of unique accessions represents an important form of insurance against loss when it is done in genebanks with long-term conservation facilities that meet international standards and are located sufficiently distant from the original site. On the other hand, unintentional or overduplication is wasteful and should be minimized. A systematic international approach to duplication is, therefore, required.[68]

Information is currently not available as to how many accessions are "unique" and how many are duplicates. However, a study published in 1987 estimated that 35% of the stored accessions for 37 crops were unique, while the rest were duplicates.[69] The study was based on 2.5 million accessions. With today's global total exceeding this figure - and reaching a figure that the steep rise in the past decade's collecting missions alone cannot explain - it must be assumed that inadvertent duplication is now even higher. Based on this premise, the recent study of global plant genetic resources undertaken by the National Research Council of the United States called for redundancies to be minimized.[70]

Fewer than 5% of the institutions in the WIEWS database provided estimates on the extent of duplication in their collections. Of the countries submitting Country Reports, about half provided some information on the degree to which their collections were duplicated, most indicating partial duplication. Of these, 11 countries reported that their collections (430,000 accessions) were fully duplicated, 51 countries reported partial duplication and ten countries reported that none of their collections were duplicated.

More complete data are available for most IARC genebanks (see Table 3.6). While the duplication status of these genebanks has improved in recent years, the extent of safety duplication still needs to be greatly improved for most collections of CGIAR's mandate crops.

### 3.5.2 The need for regeneration

Regeneration of seeds or other reproductive plant material in storage is an important part of the work of any genebank. Even under optimal *ex situ* storage conditions, viability declines and the result is a loss of both genes and genotypes. In the case of unique material, such losses may be irreplaceable. Therefore, the monitoring of viability and timely regeneration must be priority activities of all genebanks.

As well as the need for rejuvenating samples that have lost viability, further reasons for regeneration are the need to multiply seed stock to meet recommended quantities for base collections and the need to meet distribution requirements (more properly considered "multiplication").

Two factors have a major impact on regeneration needs and capacity. These are storage conditions and the capability to handle the regeneration of cross-pollinated species. Poor seed storage conditions result in the rapid loss of seed viability and the need for frequent regeneration. In addition, if the seeds are not in good condition when placed in storage, regeneration may be required quickly. Repeated regeneration can result in genetic change away from the genotypic composition of the originally collected sample, especially if selection pressure is inadvertently imposed during the process (see Annex 1). Inadequate facilities for handling cross-pollinated species can cause delays in or undermine the regeneration process in such a way that the genetic integrity of the sample cannot be guaranteed. In addition, many countries simply have insufficient funds to meet routine regeneration needs.

From the data collected during the preparatory process for the International Technical Conference it is apparent that there is a worldwide backlog of samples requiring regeneration. Agenda 21 specifically mentions the importance of regenerating existing *ex situ* collections worldwide as soon as possible.[71] Regeneration was, in fact, emphasized during the preparatory process for the International Technical Conference on Plant Genetic Resources[72] and a meeting on this topic was held in India, sponsored by FAO, CGIAR's SGRP, IPGRI and ICRISAT in December 1995.

**Regeneration requirements**

Regeneration reqirements vary according to a number of factors, including factors particular to the species, storage conditions and the quality of individual accessions. If a genebank has to regenerate its collection once every ten years, it would seem that routine regeneration needs to be 10% annually. In practice, long-term genebanks should not be forced to regenerate accessions nearly as often as every ten years; most species can easily be stored for a much longer period of time in a long-term facility. However, some 95% of the countries responding with specific information on regeneration report a far higher level of need than 10%.[73] Information that is available for 44 countries in the WIEWS database indicates that an average of 48% of total accessions require regeneration (see Figure 3.7). Information from Country Reports also indicates that of the 95 countries providing information about regeneration activities, at least 71, holding nearly 3 million (60% of total) accessions, experience some difficulties in regenerating their collections.

**Box 3.1 Genetic erosion in genebanks**

There are a number of stages in the *ex situ* conservation process which can lead to loss of genetic diversity in an accession itself, or which can change the genetic integrity of an accession. This can occur even in countries with relatively good resources for *ex situ* conservation of germplasm.

Even under the most rigorous long-term storage conditions seeds do not live forever and some genotypes may die more quickly than others. This loss of viability of a sample of seeds may be a source of genetic erosion in genebanks. When viability falls below 85% of its initial value, samples should be regenerated. Several countries state, however, that they cannot comply with this general international standard.

Frequent multiplication of an accession can also be a cause of genetic erosion, particularly when the sub-sample of seeds is too small to be representative of the genetic diversity of the whole accession.

The loss of entire collections is generally the result of an institution being closed or restructured for financial reasons, or as a result of changes in policy or programme priorities. In particular, breeders' working collections, unless catalogued into the genebank, are vulnerable to loss when the breeding programme is terminated. Field genebanks are particularly susceptible to complete loss due to natural disasters such as cyclones, bushfires and volcanoes, or as a result of disease.

A review of the United States National Plant Germplasm System, based on tests conducted between 1979 and 1989, demonstrated that 29% of the National Seed Storage Laboratory's 232,210 accessions had seed germination rates that were either unknown (21%) or less than 65% (8%). Furthermore, 45% of the accessions had fewer than 550 seeds.

In the Latin American Maize Project (LAMP), it was noted, in 1991, that only half of the accessions could be evaluated due to lack of viable seed, and that the lack of reliable storage facilities had resulted in the total loss of a large number of accessions and severe genotype deletions in many more.

Reliable long-term storage facilities are lacking in 54 reporting countries, responsible for the equivalent of 29% of accessions, while difficulties in regenerating cross-pollinated species were reported by 23 countries which hold 28% of accessions. The main constraints to regeneration reported are funding, 37 countries with 34% of accessions; lack of infrastructure and facilities, 34 countries with 32% of accessions; and lack of trained personnel, both technical and non-technical, 26 countries with 37% of accessions. The regeneration situation on a regional basis is illustrated in Figure 3.8.

The situation with respect to regeneration in the major national genebanks is outlined in Table 3.4. Only Japan, Ethiopia and Poland report less than 10% of total genebank accessions requiring regeneration. The table shows that in one of the largest genebanks, VIR in the Russian Federation, regeneration must be carried out every few years because it lacks long-term storage facilities. This obviously puts a great strain on the resources of the genebank and places the material at risk.

## Percentage of accessions in national collections remaining to be regenerated

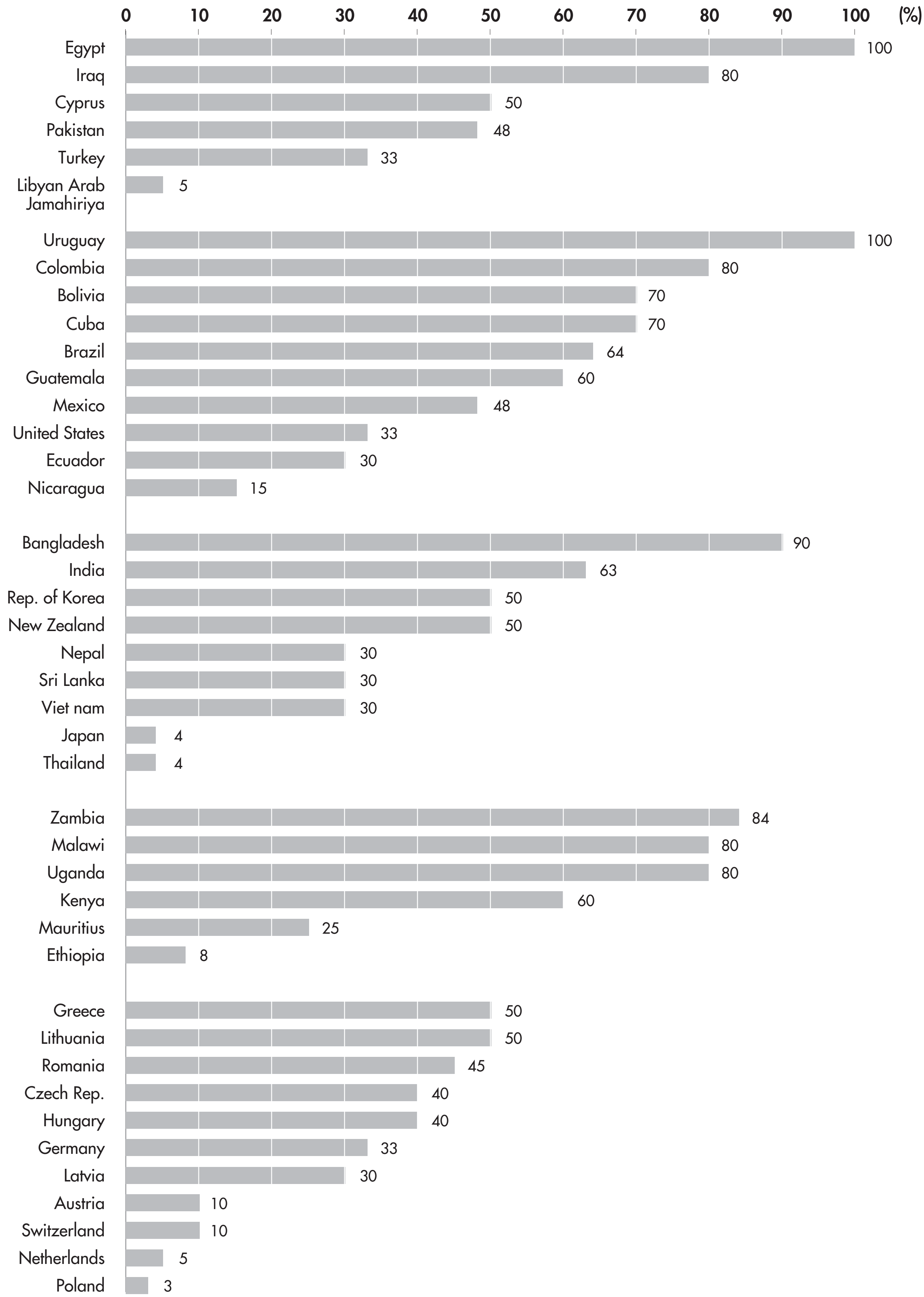



Figure 3.7

*Source:* FAO, WIEWS database

## Regeneration problems reported by countries

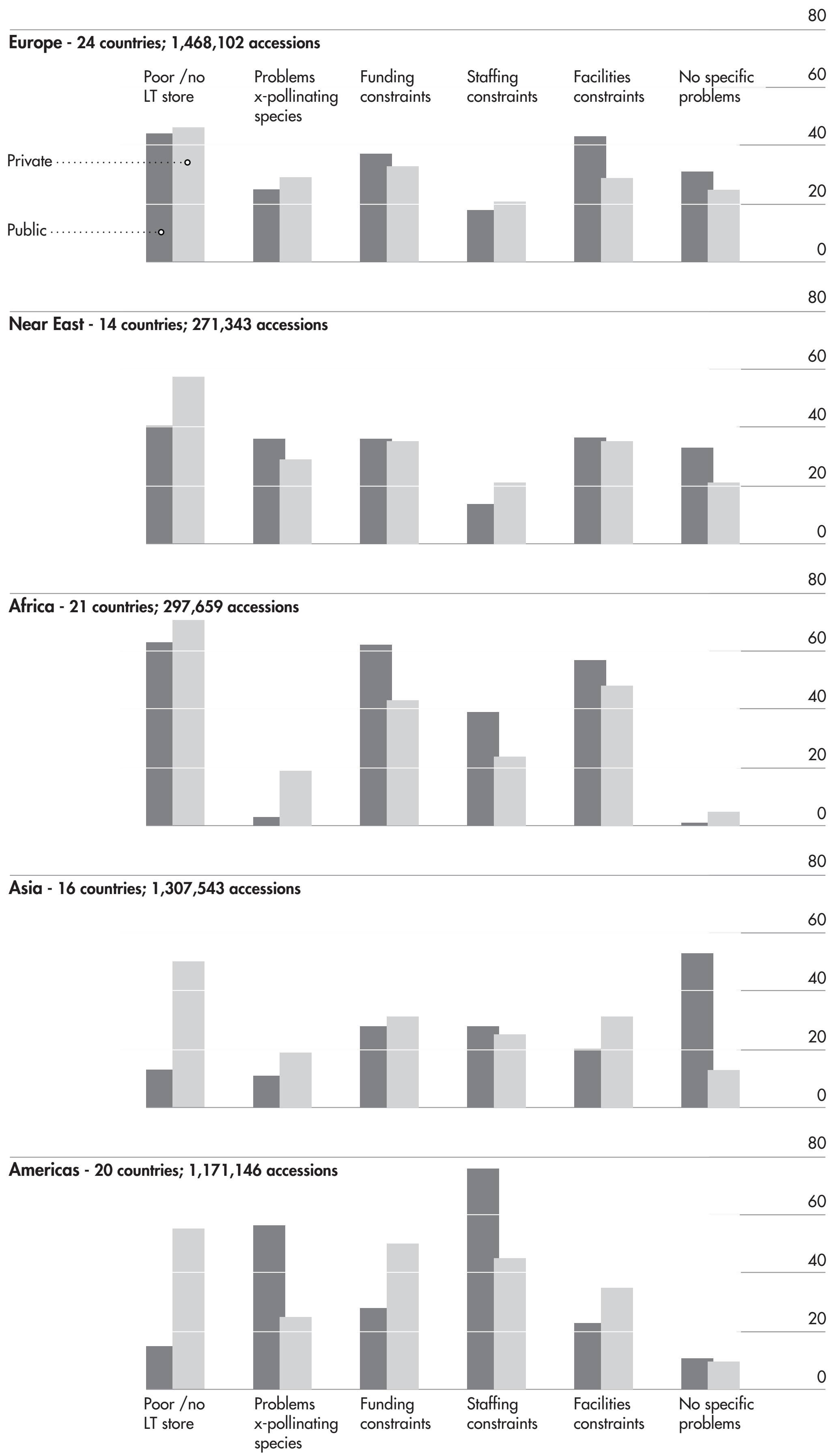



Figure 3.8

*Source:* Country Reports

Some countries involve private companies, NGOs and farmers in regeneration activities. This has, however, only been reported by four countries, namely Canada, Germany, Greece, and the Netherlands.

The Royal Botanic Gardens at Kew, the United Kingdom, has developed a policy to reduce the need for multiplication as much as possible. A sufficiently large sample is collected to avoid the need for further multiplication. An effort is then made to ensure that long-term storage conditions are maintained. In the event that fresh seed is required, this is, whenever possible, re-collected rather than regenerated from the original sample.

This system works well in the circumstances of this particular genebank, which is responsible for conserving wild relatives of crop plants, and not landraces or cultivars.

Regeneration problems have also been reported by a number of the CGIAR centres. At CIAT, many accessions have an inadequate number of seeds and regeneration is required. However, with regard to some forage accessions, re-collection may be more efficient than regeneration. At CIMMYT, although regeneration is ongoing, resources are insufficient for the size of the task required. Similarly, at CIP, lack of resources is limiting the regeneration of true seed accessions of potato and sweet potato.

The total number of accessions stored in *ex situ* genebanks is approximately 6 million. As noted in the introduction to this chapter, however, some of these are in active or working collections. Base collections contain closer to 3 million accessions. Furthermore, as noted above, there is some duplication of accessions in collections and the percentage of unique accessions is estimated to be in the order of 1 to 2 million. If the proportion of accessions that need regeneration is 48%, it can be estimated that the backlog requiring regeneration is between 500,000 and 1 million accessions. Lack of information concerning which accessions are "unique" means that a larger number of accessions would have to be regenerated to be sure of protecting existing stored diversity. Some accessions, however, may already have lost their viability or genetic integrity, or they may be from populations where recollecting may prove more cost-effective than regeneration.

The major increase in germplasm collecting in the 1970s and 1980s created a great demand for regeneration in the following two decades. Many countries were unprepared for this. Funding has not been earmarked for regeneration activities, and many recently established genebanks lack the facilities and experience to meet the challenge. The LAMP project (see Chapter Six) in which many thousands of maize accessions were regenerated, illustrates the scope of the task and could provide useful guidance for planning on a crop by crop basis.

In addition to the cost of clearing the backlog of accessions that need regeneration, sufficient funds must also be allocated to pay for routine regeneration and multiplication activities. Funds, however, are not the only requirement. Many developing and developed countries report that they lack the facilities and personnel required for handling the regeneration of cross-pollinated species. In addition, appropriate methodologies have still to be developed for the regeneration of many wild crop relatives, particularly those that are cross-pollinated.

## 3.6 DOCUMENTATION AND CHARACTERIZATION

### 3.6.1 Documentation

Much of the world's *ex situ* plant genetic resources are poorly documented. For optimal conservation and utilization, the following basic data should be available for each accession:

- basic identification criteria or "passport" data (accession number, taxonomic name, details on where and how the material was collected);
- descriptions of basic morphological and agronomic characters, known respectively as "characterization" and "evaluation" data;
- current viability test results and regeneration times;
- records of where the material has been distributed and used in breeding or other crop-improvement activities.

Curators of collections play an important role in maintaining, updating and distributing this information.[74] One problem faced by many curators however, is that evaluation data are frequently not returned to the genebank for inclusion in the database. There is also a need for more user-friendly documentation systems with standard formats to facilitate data exchange, in order to allow for the dissemination of information on characterization and evaluation to a wider audience of users. Increasing use of the Internet may help to facilitate a global information system accessible to many conservers and users of PGRFA.

### Information and documentation systems

The CGIAR centres all have fully computerized documentation systems. In addition, a System-wide Information Network on Genetic Resources (SINGER), to which they will all be linked, is under development. This system will includ passport, collecting, characterization and distribution information (see Chapter Six).

At the national level, a number of countries have fully computerized documentation systems and reasonably complete data (most European countries, the United States, Canada, Japan, China, India, Brazil, Ethiopia and Kenya). Many countries also report partial or ongoing computerization of documentation systems. In general, however, documentation of *ex situ* conservation activities and resources is inadequate.

A total of 55 countries report the need for improvement, and many emphasize the need for integrated, compatible systems which allow for easy exchange of information.

### Regional status

**Europe** Most documentation systems here are either computerized or in the process of becoming computerized. The information system of the VIR in the Russian Federation, for example, is fully computerized and data are available on the Internet. In Germany, the various institutes are served by a centralized documentation system which exists at the German Information Centre for Genetic Resources. However, in other Western European countries with decentralized germplasm collections, databases are maintained by individual institutions and centralized documentation systems do not exist.

**Near East** Only Morocco, Pakistan, the Islamic Republic of Iran and Turkey have good computerized documentation systems for a wide range of species. Other countries in the region are at various stages in developing documentation systems. In the Central Asian countries, computerized databases are non-existent and only a small percentage of accessions are fully documented.[75]

**Africa** In East Africa,[76] only Ethiopia and Kenya have well organized documentation systems of their national programmes. Mauritius,[77] in the Indian Ocean, has a documentation system that is computerized for sugar cane and *Phaseolus.* In Southern Africa,[78] the SADC's documentation and information system has been adopted by all countries. In many countries in West and Central Africa, plant genetic resources collections are maintained by breeding programmes.[79] There are often no centralized documentation systems and few countries have computerized systems. In Sierra Leone, however, there is a partially computerized cassava database and in Nigeria, although the system is not computerized, documentation exists for 80% of samples. Documentation in Ghana is also manual, but computers are expected to be introduced soon.

**Asia and the Pacific** In the East Asian sub-region,[80] China and Japan have fully computerized documentation systems containing available passport, characterization and evaluation data for all accessions. In the Republic of Korea, a centralized documentation system has been set up and data from all the institutions have been included. The Democratic People's Republic of Korea also has a computerized documentation system, but so far information on only 10% of accessions has been computerized. A computerized documentation system is under development in Mongolia.

In Southeast Asia,[81] computerized documentation systems are generally available on a crop-specific basis, and these tend to be located at the relevant research institutions. Centralized documentation systems do not exist. For example, in Malaysia, documentation systems are in place for rice, cocoa and coconut, and in Papua New Guinea, for sweet potato, cassava, taro and banana. The Plant Resources of South East Asia project (PROSEA) collates and documents the wealth of existing information on plant resources in the sub-region (see Chapter Six).[82]

Documentation of information in South Asian countries varies from country to country. In Bangladesh and Nepal, documentation is very poor; there are no computerized databases and no catalogues of information available to users. In Sri Lanka, however, a fully operational computerized database system is available for all crop species and their wild relatives. Genetic resources catalogues are also being prepared for publication. India also has a national centralized computerized database system which gathers together all relevant data from diverse sources. The National Bureau of Plant Genetic Resources (NBPGR) proposes to expand its database through regional and international linkages.

**Americas** In South America,[83] most countries have computerized their documentation systems to some extent. In addition, many countries have published catalogues on specific species maintained in their genebanks.

In contrast, development of documentation systems in Central America and Mexico and in the Caribbean is patchy; only Cuba and Costa Rica have fully computerized systems, although in Honduras and Mexico documentation systems are partially computerized. A systematic regional information network on germplasm availability and description is being established through an FAO project for the CARICOM countries with the Caribbean Seed and Germplasm Resources Information Network (CSEGRIN).

In North America, documentation systems are at an advanced stage. In the United States, data on the National Plant Germplasm System collections are maintained in the Germplasm Resources Information Network (GRIN) database. GRIN is a centralized computer database that includes all passport, inventory, evaluation and order processing records for the NPGS. All available passport data are included in GRIN for accessions that entered the NPGS after 1979. Most accessions also have some characterization and evaluation data associated with them, the extent of which varies from species to species. Direct access to the GRIN database is available through the Internet from anywhere in the world. In Canada, a new database system, the Canadian Agricultural Plant Genetic Resources Information System (CAPGRIS) has been under development since 1988, and interactive on-line services for external clients through the Internet are planned.

**Extent of passport data by region**

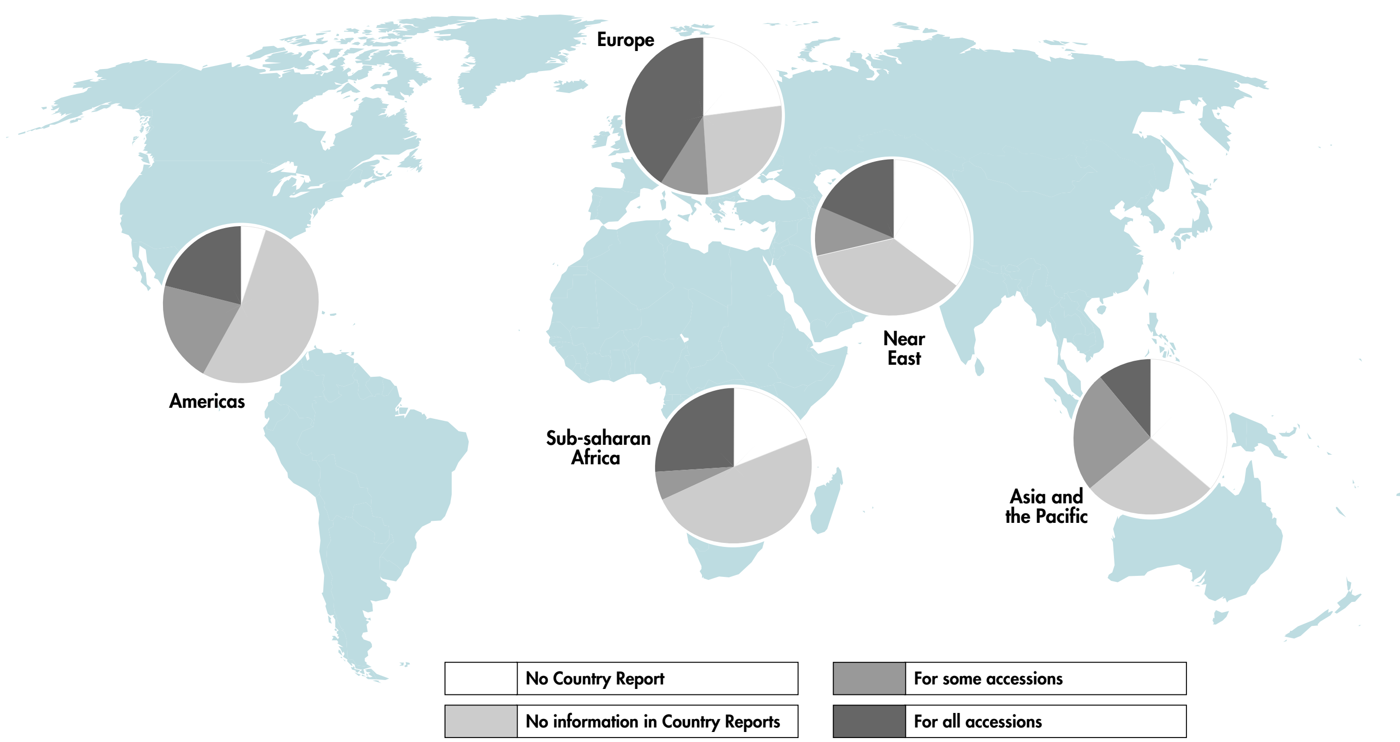



Figure 3.9 *Source:* Country Reports

### Passport data

Around the world, 48 countries report that passport data are available for all the accessions in their national collections. This covers approximately two million accessions, or some 37% of accessions held in national collections. In addition, 28 countries report that passport data are available for some, but not all of their accessions. Passport data also exist for most of the accessions maintained in the CGIAR genebanks.

**Extent of characterization of *ex-situ* collections: selected countries**

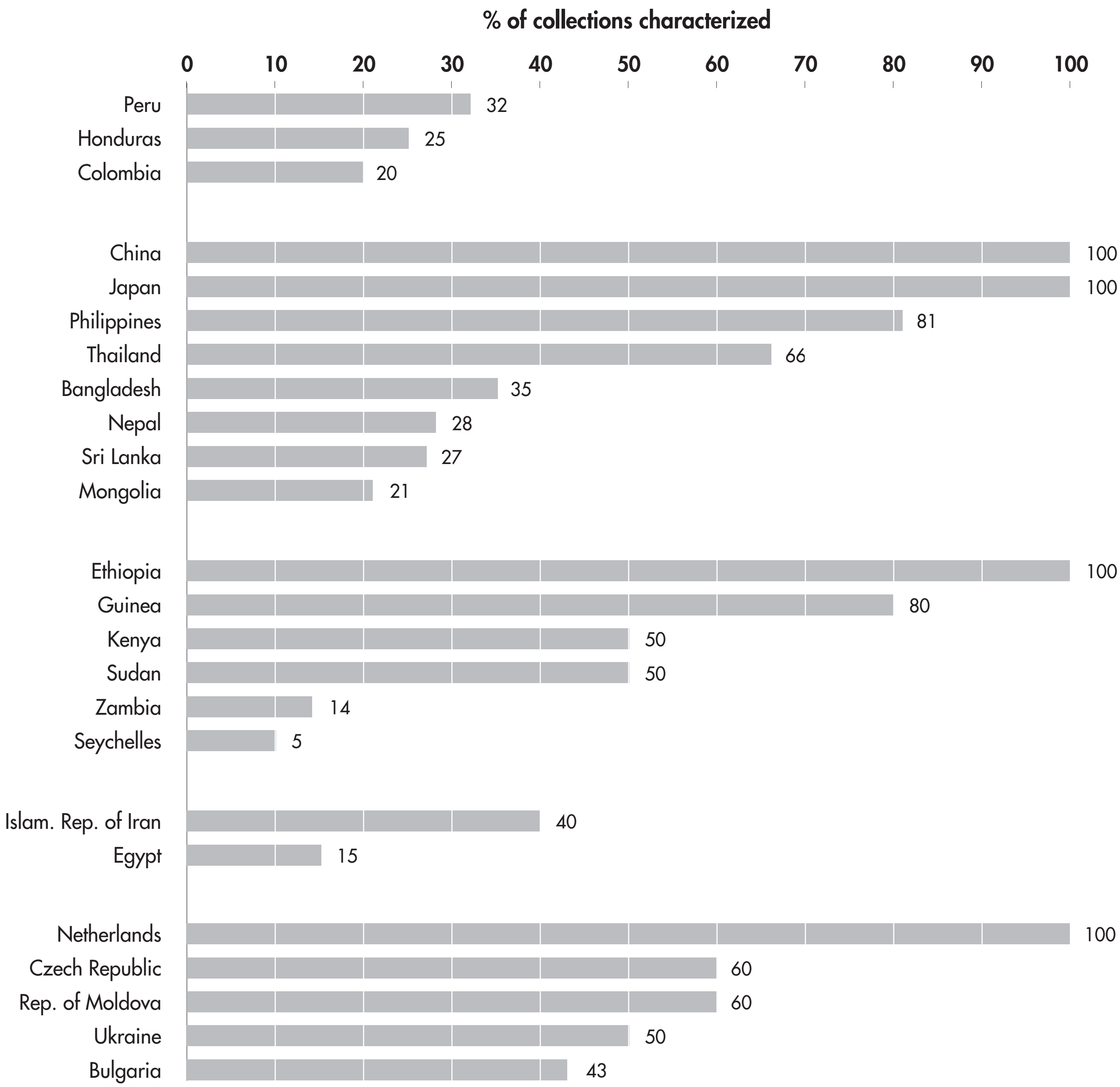



Figure 3.10 *Source:* Country Reports

The amount of information included in the passport data of accessions in many collections may, however, be minimal. In 1984, it was found that for most collections the only information available was the country of origin,[84] but the statistics, available may differ significantly between species. For example, precise data on origin (latitude and longitude) were available for 78% of the world's *ex situ* holdings of wild *Triticum* and *Aegilops* species.[85] Ethnobotanical information on the history and local uses of germplasm is usually scant and not available in the database systems. The practice of collecting herbarium voucher specimens and ensuring that the data on these are permanently linked to data on the seed samples is generally not effectively managed. Finally, it should be noted that the absence of supporting data is the reason commonly given by plant breeders for making their own collections, rather than relying on material from genebank collections. Figure 3.9 indicates the extent of passport data on a regional basis, according to the Country Reports.

### 3.6.2 Characterization

Characterization of accessions provides the information on morphological and agronomic aspects of material which is essential for genebank management. As with evaluation data, some characterization data can also be useful to plant breeders. (Refer to Annex 1-2 for more information. The evaluation of germplasm collections is covered in Chapter Four.)

During the preparatory process for the International Technical Conference, the lack of characterization and evaluation data was the most commonly expressed reason for the underutilization of accessions held in national collections. It is also the most common constraint to increased utilization of PGRFA cited by breeders and other researchers in scientific literature.

Information on characterization activities is included in only 56 Country Reports, and the information given varies widely. In most countries in Europe, East Asia and North America, collections are well characterized. This is also true of Ethiopia, India and the Philippines. Elsewhere, the extent of characterization is uneven, as is illustrated in Figure 3.10. The extent of characterization of the major mandate crops of the CGIAR centres is provided in Annex 2.

In many cases, characterization is limited to only a few of the species represented in the genebank, usually those species that are major food or commodity crops, as Table 3.7, based on information provided in Country Reports, shows. In other cases, characterization has been carried out on a larger number of accessions but using a limited number of descriptors.

**Table 3.7 Characterization of accessions in selected national *ex situ* collections**

| Country | Extent and crop coverage |
|---|---|
| Angola | Some - sorghum, sunflower and groundnut |
| Benin | Some - maize, sorghum, cassava and rice |
| Botswana | Sorghum, pearl millet, cowpea, bambara groundnut |
| Madagascar | Rice, legumes, wild coffee |
| Mauritius | *Phaseolus* and sugar cane |
| Namibia | Pearl millet, sorghum, groundnut |
| Senegal | Cotton |
| Republic of Korea | 40% of sesame collection |
| Papua New Guinea | 100% - sweet potato, cassava, aibika; variable for other species |
| Viet Nam | Priority is given to the main crops: rice, sweet potato, taro, yam, soybean, citrus |
| Costa Rica | Some - pepper, citrus, mango, luffa, beans and maize |
| El Salvador | Maize, beans, sorghum, rice |
| Guatemala | 80% of some species |
| Mexico | Extensive characterization of germplasm of 26 crops |
| Nicaragua | Between 20% and 100% of various collections |
| Argentina | 100% of maize, 90% of sorghum, <20% of wheat and soybean |
| Bolivia | Potato and ocra |
| Brazil | Little |
| Chile | Beans, maize and potatoes |
| Guyana | Rice, sugar cane |
| Paraguay | Maize, sweet potato |
| Trinidad and Tobago | Cocoa |

*Source:* Country Reports

Many countries report the need for further characterization of collections, and some report the need for assistance in this area.[86] A number of countries also note the need for further development of molecular techniques for germplasm characterization and the identification of diversity and duplication.[87]

Most genebanks are characterizing their collections based on international descriptors, such as those published by IPGRI (see Annex 1). Some countries, in particular the African lusophone countries, have encountered problems, because there is no list of morphological descriptors available in their official language.[88]

## 3.7 GERMPLASM MOVEMENT

An important role of genebanks is to promote and facilitate the distribution of germplasm. This may involve international movement of germplasm (see Chapter Seven) as well as distribution at the national level, usually to plant breeders and other researchers, but also directly to farmers, as proposed in Chapter Two.

Although the percentage of total accessions distributed from genebanks may be small (see also Chapter Four), the total numbers involved can be large. For example, over the last three years, the CGIAR centres have distributed an annual average of more than 50,000 accessions to national programmes all over the world.[89] Similarly, between 1992 and 1994, the United States received requests for germplasm of 3,057 species, which represents about a third of the species conserved, and distributed over 100,000 samples each year.[90]

In general, germplasm has been freely available to bona fide users upon request. Increasingly, however, access restrictions are being introduced (see Chapters Five and Seven).

In most countries the movement of germplasm is subject to quarantine regulations in order to prevent inadvertent importation of pests and diseases. Such regulations are particularly important for controlling the movement of vegetatively propagated crops, whose health status, especially with regard to virus infections, can be difficult to ascertain (Annex 1).

This can affect the distribution of germplasm, as for example, INIBAP's *Musa* collection, of which only 40% is available for distribution; the remainder awaits virus indexing. The development of tissue culture facilities, together with virus indexing procedures, is therefore a necessity for many countries.[91]

## 3.8 BOTANICAL GARDENS[92]

Botanical gardens maintain living collections of plant genetic resources. Sometimes they also have seed banks or *in vitro* collections. Many are involved in taxonomical and other types of research. They also perform a useful educational role. There are 1,500 botanical gardens in the world, 186 of which are members of the International Association of Botanic Gardens (IABG). In addition, 250 botanical gardens with active conservation programmes are members of Botanic Gardens Conservation International (BGCI).

Species of importance for medicinal and ornamental purposes, as well as plant genetic resources for food and agriculture of essentially local significance, are often more fully represented in botanical gardens' collections than in traditional collections of plant genetic resources for food and agriculture. Botanical gardens can, therefore, fill an important gap in *ex situ* conservation programmes. Botanical gardens may also have a comparative advantage in conserving some vegetatively propagated plants and those with recalcitrant seeds and, more particularly, trees and other slow-growing species. The need for a comprehensive approach to *ex situ* conservation and the inclusion of botanical gardens and arboreta in such programmes was emphasized by many countries in the Sub-regional Synthesis Reports.[93]

The number of accessions conserved per taxon in botanical gardens usually ranges between two and three. This indicates that while botanic gardens conserve considerable amounts of inter-species diversity they conserve very little intra-species genetic diversity. This is probably due to the fact that their interest and mandate generally extends to all plant species and not just those considered to be of importance to food and agriculture, with its emphasis on using diversity for breeding purposes.

### 3.8.1 Conservation facilities and statistics

The majority of botanical gardens (61%) are situated in Europe, the countries of the former Soviet Union and in the United States. About 11% of botanical gardens are privately owned. Worldwide, 698 (47%) botanical gardens can be considered to have germplasm collections,[94] 80% of which are preserved as living collections outdoors or in greenhouses. Approximately 75% of the germplasm conserved in botanical gardens worldwide is preserved in North America and Europe.

Among the 698 botanical gardens which have germplasm collections:

- 410 conserve ornamental species or wild native endangered species, many of these from taxa closely related to major crops. Approximately 60% of these collections are in the EU, United States and Japan, but South Africa and Mexico also have such collections;
- 169 also conserve medicinal and forest species. These types of collections are found particularly in China, Japan, India and Brazil;
- an additional 119 botanical gardens conserve germplasm of cultivated species, including landraces, semi-cultivated species and other species which although not cultivated are locally utilized. Most of these collections are found in Asia (mainly India and China) and Mesoamerica (mainly Mexico). Botanical gardens in Canada also maintain such collections.

**Conservation of PGRFA in botanical gardens**

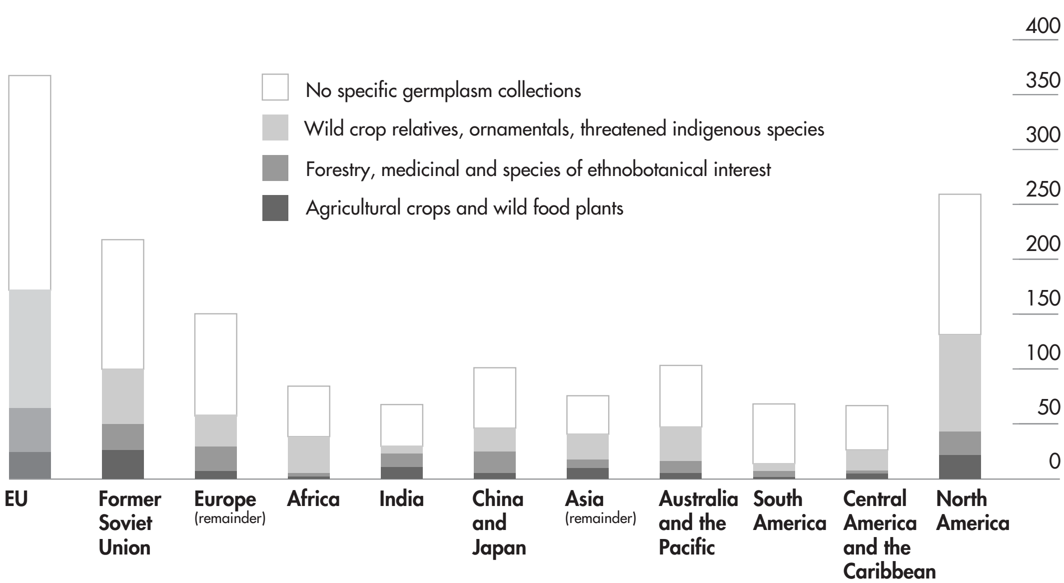



Figure 3.11

In addition, it is estimated that 150 botanical gardens have germplasm seed genebanks. Of particular note are the seed genebanks of the Royal Botanic Gardens at Kew and the Botanic Gardens in Copenhagen, Denmark.[95] Facilities for *in vitro* propagation are available at 35 botanical gardens, although they are rarely utilized for germplasm preservation.

### 3.8.2 Documentation and germplasm exchange

Sixty percent of the botanical gardens which preserve germplasm have either a manual (75%) or computerized database (25%). However the situation in most European countries, and perhaps in others, is that although holdings may be recorded, they are not, generally, integrated into overall conservation strategies for the species in question. Therefore, such integration remains to be carried out by most of the national programmes in the region.[96] With regard to germplasm origin, it is only possible to ascertain the precise origin for approximately half of the accessions conserved in botanical gardens.[97]

Some countries in Africa[98] are using the Botanical Research and Herbarium Management Systems (BRAHAMS) to develop databases on indigenous food plants, traditional knowledge, rare and endangered species, endemic plants and medicinal and ornamental plants. In addition, in Southern Africa, there is a regional project to strengthen botanical gardens and herbaria which is funded by the Global Environment Facility.[99]

One of the main international mechanisms for germplasm exchange is the germplasm catalogue known as the *Index seminum,* published annually. For 300 years this index has been one of the most important sources of germplasm worldwide. It is estimated that 2 million germplasm accessions are offered every year through the *Index seminum* system. It seems, however, as is the case with plant genetic resources for food and agriculture genebanks, that botanical gardens rarely receive feedback on how the germplasm is used.

## 3.9 ASSESSMENT OF MAJOR *EX SITU* NEEDS

As has been noted several times throughout this Chapter, data for many aspects of *ex situ* conservation are incomplete. Nevertheless, some clear points emerge:

- Approximately six million samples have been placed in genebanks.
- It is widely agreed that although a large amount of diversity has been collected, this does not completely cover the total genetic diversity of all crops. Specific gaps that have been identified include the coverage of wild crop relatives and landraces, particularly in relation to minor and underutilized crops.
- Many important species do not have orthodox seeds and cannot be stored in seed genebanks. These species tend to be underrepresented in germplasm collections.
- While many countries lack the resources to maintain the material that they, or the international community, have already paid to collect, others have excess storage capacity. Even countries with suitable physical infrastructure may not have sufficient resources to manage their collections adequately.

- While each continent contains small number of genebanks operating in conformity with the highest international standards, much of the material in the remaining facilities is stored under conditions that threaten its genetic integrity. Even the best facilities are not always immune to problems of funding.
- While safety duplication is far from complete, there may be a significant amount of over-duplication of samples.
- There is a large and growing backlog of material due for regeneration.
- Available data on conserved accessions are highly variable and incomplete.
- Access to useful information on conserved material is also very limited.

The collections in today's genebank "system" were largely formed during the crisis years of the 1970s and early 1980s in response to genetic erosion. Experts believed - with good reason - that they had very little time in which to collect these resources and safeguard them from extinction in the field. The urgency of the moment and the haste in which action was taken led to two achievements: (i) the deployment of a wide range of resources, including institutional structures, funding sources, strategies, personnel and rapidly constructed genebanks, to tackle the crisis; and (ii) the rescue and amassing of a huge collection of plant genetic resources. The emphasis at the time was on the collection and conservation of material rather than on the management and utilization of conserved accessions.

As we enter the 21st century, we do so with all the strengths — and drawbacks — of this recent history.

Throughout the preparatory process, it has become increasingly clear that capacities for *ex situ* conservation need to be strengthened in a number of important ways. However, it is also widely recognized that the sustainability of conservation efforts depends on maintaining collections in a cost-effective manner.[100] Emphasis, therefore, must be on measures which improve the efficiency of conservation through the rationalization of efforts and the use of low-cost conservation methods.[101]

In particular, the following needs and measures are indicated:

- the need for rationalization of collections through regional and international collaboration and the sharing of facilities and resources wherever possible;
- the need to promote efficiency in germplasm management and use (e.g. the use of core collections and a common database) and to improve general management practices;[102]

- the identification of priorities to fill gaps in collections;[103]
- the development of low-cost conservation technologies and, in particular, of technologies for non-orthodox seed and vegetatively propagated plants, including *in vitro* methods and cryopreservation;[104]
- the need for a global regeneration effort;
- the need to complete safety duplication of collections while also reducing unnecessary overduplication of accessions;[105]
- the need for primary characterization, evaluation and enhancement and adequate documentation to facilitate collaboration with plant breeders and to promote the sustainable use of plant genetic resources by all users;[106]
- the need to develop pathogen-tested collections.

Further, the requirement for complementary conservation strategies, employing both *in situ* and *ex situ* techniques, and the need to improve the linkages between conservation and utilization were also emphasized.[107]

Finally, the need to maximize synergy through appropriate collaboration at national, sub-regional, regional and international levels is noted, including sharing the burden of long-term *ex situ* conservation through the rational organization of base, active and working collections.[108]

This might include mechanisms to allow countries to place materials in secure storage facilities outside their borders, without compromising their sovereign rights over such material (see Chapter Seven).[109] Various financing mechanisms may be required to facilitate such a rationalization of activities.

■

## Chapter 3 endnotes

1 FAO (1995) Progress Report on the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture, Document CPGR 6/95/13 of the Sixth Session of the FAO Commission on Plant Genetic Resources, 19-30 June 1995. Rome.

2 This number is obtained by using the larger of the numbers of accessions per country as reported in the Country Reports and in the WIEWS database. Discrepancies in the numbers from the two sources are frequently caused by the inclusion or exclusion of working collections. Full data are provided in Appendix 2.

3 Brazil, Canada, China, France, Germany, India, Japan, Republic of Korea, Russian Federation, Ukraine, United Kingdom and United States.

4 Information from the FAO WIEWS database.

5 FAO (1995) *Survey of existing data on* ex situ *collections of plant genetic resources for food and agriculture*. CPGR 6/95/8 Annex of the Sixth Session of the FAO Commission on Plant Genetic Resources, 19-30 June 1995. Rome.

6 E.g. maize in Central America and the Caribbean and hexaploid wheat in Tibet (CIMMYT) threatened pasture and forage species in the West Asia and North Africa region (ICARDA), and *Musa* in South China, Indonesia and the Indian Ocean Islands (INIBAP). See Annex 2 for more details.

7 Subregional Synthesis Report: East Africa, para 81.

8 At least 43 countries according to information from Country Reports.

9 East Africa, the Near East and East Asia.

10 Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 2; Subregional preparatory meeting: South America Report, programme 4.1.

11 Subregional Synthesis Report: Europe, para 83.

12 Subregional Synthesis Report: South and East Mediterranean, para 32; Subregional Synthesis Report: West Asia, para 48.

13 Subregional Synthesis Report: Central Asia, Section II C.

14 Subregional Synthesis Report: East Africa, para 81.

15 Subregional Synthesis Report: Southern Africa, para 59.

16 Subregional Synthesis Report: Southern Africa, para 62.

17 Subregional Synthesis Report: West Africa, para 67.

18 Subregional Synthesis Report: South Asia, para 2.13.

19 Country Report India.

20 Subregional Synthesis Report: East Asia, para 46.

21 Country Report China.

22 Subregional Synthesis Report: East Asia, para 49.

23 Subregional Synthesis Report: East Asia, para 50.

24 Subregional Synthesis Report: Southeast Asia.

[25] Information from Country Reports.

[26] Ibid.

[27] Country Report Brazil.

[28] 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 found in WIEWS data. 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.

[29] It should be noted that the total number of accessions of a crop may not be an accurate indication of how well the diversity of that crop is represented in collections. For example, a crop with only a small percentage of world accessions may nevertheless be quite well sampled. All other things being equal, however, the total number of accessions provides an indication of *ex situ* conservation efforts for that crop.

[30] Haq N (1995) personal communication, International Centre for Underutilized Crops, University of Southampton, UK.

[31] Considering all accessions, the proportion in the advanced cultivars/breeders line category could be anywhere between 16% (those known to be of this category) to 82% (i.e. if all unknown accessions are actually in this category). Similarly, the true proportion of accessions in the landraces/old cultivars category could be anywhere between 12% and 77%, while wild and weedy relatives could be anywhere between 5% and 60%.

[32] A total of 66 countries report that they have designated national genebanks.

[33] Subregional Synthesis Report: Europe, para 84.

[34] System-wide Programme on Plant Genetic Resources (1996) *Report of the Internally Commissioned External Review of the CGIAR Genebank Operations.* IPGRI Rome.

[35] Plucknett DL, Smith NJH, Williams JT and Anishetty NM (1987) *Gene banks and the world's food.* Princeton University Press, New Jersey, USA.

[36] Op. cit., endnote 30.

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

[38] It should be noted, however, that even in many of these genebanks, full safety duplication is lacking, and there is often a large backlog of accessions for regeneration. Moreover, managerial and equipment problems are not unknown, even in some of the most technically advanced facilities.

[39] Subregional Synthesis Report: South and East Mediterranean, paras 42-49.

[40] Subregional Synthesis Report: West Asia, paras 55-60.

41 Subregional Synthesis Report: East Africa, para 85.

42 Subregional Synthesis Report: Indian Ocean Islands, para 60; Country Report Mauritius.

43 Institutes in Nigeria and Ghana received support from IPGRI and FAO for the consolidation of their facilities.

44 Guinea, the Niger and Senegal have received external aid for the installation of cool chambers for seed storage, but the installations have broken down and are unusable.

45 Subregional Synthesis Report: West Africa, para 74.

46 Subregional Synthesis Report: Southern Africa, para 64.

47 Subregional Synthesis Report: South Asia.

48 Subregional Synthesis Report: Southeast Asia.

49 Subregional Synthesis Report: South America, para 44.

50 The Inter-American Development Bank provided funds for a seed storage facility in El Salvador, but problems in operating the facility and in seed drying have been encountered.

51 Subregional Synthesis Report: Central America and Mexico, para 47.

52 At times, the facility has faced problems with power supplies.

53 Op. cit., endnote 34.

54 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii).

55 Op. cit., endnote 34.

56 Information from Country Reports.

57 Information from FAO WIEWS.

58 Ibid.

59 Ibid.

60 Country Report China.

61 Information presented at Expert Consultation on the Management of Field and *In Vitro* Genebanks, Colombia, 1996, organized by FAO, SGRP, IPGRI and CIAT.

62 Subregional Synthesis Report: South Asia.

63 Information from FAO WIEWS.

64 Ibid.

65 Op. cit., endnote 4.

66 Congo, Côte d'Ivoire, Gabon, Ghana, Kenya, Madagascar, Mauritius, Senegal, Togo and Zaire.

67 Subregional Synthesis Report: East Africa, para 91.

[68] Subregional preparatory meeting: South America Report, recommendation (iv) (b); Subregional preparatory meeting: North America Report, recommendation 2 (b); Subregional preparatory meeting: East Asia Report, recommendation 18; Subregional preparatory meeting: East Asia Report para, 18.

[69] Op. cit., endnote 35.

[70] National Research Council (1993) *Managing global genetic resources: agricultural crop issues and policies,* p. 20. National Academy Press, Washington, D.C.

[71] Agenda 21: Chapter 14G of Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Sustainable Agriculture.

[72] Subregional preparatory meeting: South America Report, recommendation (iv)(b).

[73] Information from FAO WIEWS. In some cases, countries may confuse multiplication needs with regeneration needs. Multiplication needs result from demands from germplasm as opposed to low viability.

[74] Subregional preparatory meeting: Mediterranean Report, para 34; Subregional preparatory meeting: Europe Report, recommendation (c).

[75] Subregional Synthesis Report: Central Asia, Section C.

[76] Subregional Synthesis Report: East Africa, para 97.

[77] Subregional Synthesis Report: Indian Ocean Islands, para 67.

[78] Subregional Synthesis Report: Southern Africa, para 67.

[79] Information from Country Reports.

[80] Subregional Synthesis Report: East Asia, para 63.

[81] Subregional Synthesis Report: Southeast Asia.

[82] Ibid.

[83] Information from Country Reports.

[84] Peeters JP and Williams JT (1984) Toward better use of genebanks with special reference to information. *Plant Genetic Resources Newsletter*, 60:22-32.

[85] Hodgkin T (1991) The core collection concept. In: *Crop networks - new concepts for genetic resources management*. International Crop Network series 4. IBPGR, Rome.

[86] E.g. Seychelles, Malawi, Guinea, Albania.

[87] Country Reports India, Nepal, Niger, Slovakia.

[88] Subregional Synthesis Report: West Africa, para 76.

[89] Op. cit., endnote 34.

[90] Country Report United States of America.

[91] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 8.

[92] This section is largely based on: Hernández Bermejo J.E. (1996) Información sobre las colecciones *ex situ* conservadas en jardines botánicos. Background Study Paper n. 5, Commission on Genetic Resources for Food and Agriculture. FAO, Rome.

93 Subregional Synthesis Report: West Africa, para 80; Subregional Synthesis Report: South and East Mediterranean, para 90; Subregional Synthesis Report: Europe, para 77; Subregional Synthesis Report: Southeast Asia; Subregional Synthesis Report: East Asia, para 72.

94 As determined by having sufficient numbers of samples per accession and sufficient capacity to manage the collection, including adequate documentation of accessions.

95 Subregional Synthesis Report: Europe, para 70.

96 Subregional Synthesis Report: Europe, para 77.

97 Op. cit., endnote 92.

98 E.g. Kenya and Namibia.

99 Subregional Synthesis Report: Southern Africa, para 70.

100 Subregional preparatory meeting: East Asia Report, para 14.

101 Subregional preparatory meeting: East Asia Report, para 18.

102 Subregional preparatory meeting: North America Report, recommendation 2(a).

103 Ibid.

104 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 4; Subregional preparatory meeting: East Asia Report, para 18.

105 Subregional preparatory meeting: North America Report, recommendation 2(b); Subregional preparatory meeting: East Asia Report, recommendation 18.

106 Subregional preparatory meeting: North America Report, recommendation 6(c); Subregional preparatory meeting: Europe Report, recommendation 26(c).

107 Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, Section 1.2 (18); Subregional preparatory meeting: North America Report, recommendation 8; Subregional preparatory meeting: South America Report, principle area of activity (b); Subregional preparatory meeting: East Asia Report, para 25.

108 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xviii); Subregional preparatory meeting: North America Report, recommendation 2(a); Subregional preparatory meeting: West and Central Africa Report, para 33; Subregional Preparatory Meeting: Southern Africa Report, recommendation (xvii).

109 Subregional preparatory meeting: East Asia Report, para 14; Subregional preparatory meeting: West and Central Africa Report, para 37; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xiii); Subregional preparatory meeting: Southern Africa Report, para 12(iii).

# CHAPTER 4
# The State of Utilization

## 4.1 INTRODUCTION

### The importance of utilization

Plant genetic resources are conserved in order that they may be used now and in the future. With population pressures rising and less and less land available for agriculture, global food production and yields will have to increase, even allowing for improvements in distribution. Most such productivity increases will depend on crop improvement which can only be achieved through the increased utilization of the plant genetic resource base. The need for greater utilization of plant genetic resources, both directly and indirectly, through plant breeding, is urgent.

Sustainable utilization, including the better deployment of genetic resources, contributes directly to conservation. Improving the utilization of PGRFA also strengthens conservation indirectly, as increased and better use of genetic resources provide incentives for more effective conservation.

The use of PGRFA is key to the fair and equitable sharing of the benefits derived from these resources. Utilization is the key benefit of PGRFA, with consumers being the ultimate and greatest beneficiaries. Although the sharing of benefits through their redistribution is important, more direct ways of realizing benefits are needed, such as wider evaluation, enhancement and utilization of local germplasm. This aspect was particularly emphasized during the preparatory process for the International Technical Conference.[1] The importance of utilization in contributing to the sharing of benefits was recognized by the Commission on Plant Genetic Resources and by the FAO Conference in its Resolution on Farmers' Rights (see Chapters Six and Seven). One of the objectives of this resolution is to: "allow farmers, their communities, and countries in all regions, to participate fully in the benefits derived, at present and in the future, *from the improved use of plant geneticresources*, through plant breeding and other scientific methods" (emphasis added).[2]

Because of the importance of PGRFA utilization, the Commission on Plant Genetic Resources agreed that the Report on the State of the World's Plant Genetic

Resources and the Global Plan of Action should emphasize both conservation and use, and treat them in an integrated way.[3]

### What is "utilization"

Ultimately, plant genetic resources are utilized through the cultivation of farmers' local varieties and varieties developed by professional plant breeders, the harvesting of wild food plants, the management of grasslands in pasture systems and the exploitation of forests. At an intermediate stage, plant genetic resources are used by plant breeders to develop new varieties. Evaluation of plant genetic resources and their "enhancement" in "pre-breeding" programmes, as well as seed production and distribution are all forms of "utilization". Marketing and the processing of products derived from the use of plant genetic resources might also be considered within the scope of "utilization". The utilization of plant genetic resources, therefore, refers to a wide range of activities, far wider than the "plant breeding" which often tends to be equated with "utilization".[4]

### Utilization of landraces

Many farmers use locally adapted landrace varieties.Landraces have been an important source of individual characteristics introduced into new varieties by modern plant breeders. In many cases, the genetic material provided by landraces has been augmented by genetic material from wild crop relatives in the breeding of modern varieties.[5] Examples of the contribution of landrace and wild relative genes to modern varieties are presented in Chapter One. Occasionally, landraces are also used to broaden the genetic base of crops through the recurrent selection of landrace material in the environment for which new varieties are required.

Landraces can thus be used in the following ways:

- as sources of individual traits for plant breeding programmes through introgression into modern varieties;
- as sources of polygenic diversity to broaden the base of plant breeding programmes through pre-breeding (incorporation) activities;
- as locally adapted germplasm upon which to base the development of locally adapted varieties;
- directly, through their multiplication and distribution to farmers.[6]

Varieties can also be a source for the improvement of landraces. Farmers, not uncommonly, incorporate traits from modern varieties into their landraces.

## Organization of this chapter

In this Chapter, the extent of PGRFA utilization is reviewed, including the distribution of conserved material. In addition, constraints to PGRFA utilization are identified and possible ways of overcoming these are discussed. The following activities are then reviewed in relation to their contribution to food security and meeting the needs of farmers:

- germplasm evaluation;
- germplasm enhancement (pre-breeding);
- plant breeding and crop improvement (including a review of national capacities and a discussion of the scope and different strategies of plant breeding programmes);
- seed production and distribution;
- marketing.

Issues related to the deployment of genetic resources are then discussed. These include issues of crop uniformity and vulnerability, and strategies for breeding for resistance to pests and diseases. Finally, major needs are assessed at the end of the Chapter.

# 4.2 UTILIZATION AND MAJOR CONSTRAINTS TO THE USE OF CONSERVED PGRFA

## 4.2.1 Distribution and utilization of plant genetic resources

### Distribution and use of PGRFA conserved in national genebanks

There is little information on the utilization of conserved PGRFA for breeding and other purposes. There is a need for information on the number of distributed accessions screened for useful characteristics, and the number of distributed accessions then actually used in breeding programmes, in order to conduct an accurate assessment of the actual use of PGRFA from genebanks in breeding programmes. This information is not available at present from most genebanks. One of the few available indicators of utilization of PGRFA from national genebanks is the number of accessions distributed each year, expressed as a percentage of the number of accessions in the genebank. In the absence of other information, this admittedly crude indicator is used below.

Only a handful of the 66 countries, which report that they have national genebanks, distribute more than 10% of accessions annually; a figure which, in and of itself, does not necessarily prove low usage. These include: Cuba, the United States, Argentina, the Republic of Korea, Thailand and Germany. However, most plant breeding programmes have their own working germplasm collections which are their main source of material for breeding. This may explain why utilization of germplasm from national genebanks by breeding programmes appears low. In a breeding programme it is typically unnecessary and impossible to work with large quantities of unadapted germplasm.

The quality of utilization is not measured by how many accessions are employed, but by how well the conserved material is employed - to what extent the needed characteristics are found and used. It is also apparent that many genebanks distribute material from only a limited number of the total species conserved. For several of the larger national genebanks, a substantial proportion of accessions distributed are provided to other countries. Over a third of the accessions distributed by the national genebanks of Brazil, Germany and the United States are sent abroad, for example. Further information on distribution of germplasm between countries is provided in Chapter Seven (section 7.3). The following is a review of the distribution of accessions region by region.

**Europe** Most countries do not report the distribution of much of their material to plant breeding programmes. For example, Germany reports the distribution of around 17% of accessions annually of which less than 20% are supplied to breeding programmes.[7] The Czech Republic reports that almost all distributed samples belong to only 30% to 40% of the species maintained in the genebank.[8]

**Near East** Only one of the nine countries with national genebanks, Pakistan, reports any significant distribution of material to national breeding programmes — 10% a year. Other countries reported little, if any, distribution of accessions.

**Africa** Of the 32 African countries with national plant breeding programmes, 16 do not have a national genebank. In these countries, plant genetic resources are conserved by the breeding programmes themselves and are classed as working collections. The other 16 countries, however, do have national genebanks, but their utilization by national breeding programmes is generally low; most countries distribute few, if any, of their accessions. An exception is Ethiopia, which distributes a relatively large proportion of its accessions, mainly indigenous varieties of cereals, legumes and oil crops, for national research and crop improvement.[9] In Southern Africa, due to institutional constraints and the lack of characterization, local collections of germplasm are rarely utilized in breeding programmes. In Angola and Mozambique, this is because the plant breeding departments have been unable to function due to internal strife. In Namibia, while some accessions of pearl millet and sorghum are used in the regional Sorghum and Millet Improvement Programme, plant genetic resources collections are under-utilized by local scientists.[10]

**Asia and the Pacific** National genebanks exist in 14 Asian countries, but only Thailand reports a high level of distribution of accessions: an average of 50% per year for those crops with active breeding programmes. However, even here, around 20 to 30 of the species maintained in the genebanks have not been used for in-country projects.[11] Other countries distribute up to 14% of accessions annually. Few Pacific countries have national genebanks. Statistics from China, however, provide interesting information on the utilization of germplasm collections in breeding programmes. From 1986 to 1990, 200,000 accessions of crop germplasm were evaluated for specific useful agronomic characteristics. Nearly 20,000 were found to have single or multiple superior characteristics and only 1,900 were used in breeding programmes or for production. This amounts to approximately 1% of the total material evaluated, and about 10% of the material identified with superior characteristics.

## Table 4.1 Average annual distribution of germplasm inside and outside the CGIAR centres, 1992 to 1994

| Centres | Number of accessions and % of collection | | | | | | | | Samples distributed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | To IARCs* | | To developing-country NARS | | To developed-country NARS | | To private sector** | | Total no. of samples distributed | % samples distributed inside the centre | % samples distributed outside the centre |
| | No. | (%) | No. | (%) | No. | (%) | No. | (%) | No. | % | % |
| **CIAT** | | | | | | | | | | | |
| *Phaseolus* | | (10%) | 737 | (2%) | 488 | (1%) | 8 | (0.02%) | | 82 | 18 |
| *Manihot* | 91 | (1.5%) | 201 | (3%) | 117 | (2%) | 5 | (0.1%) | 513 | 17 | 83 |
| Tropical forages | | (6%) | 609 | (3%) | 435 | (2%) | 70 | (0.3%) | | 34 | 66 |
| **Total** | **5,812** | **(8%)** | **1,547** | **(2%)** | **1,040** | **(1.5%)** | **83** | **(0.1%)** | **14,835** | **61** | **39** |
| **CIMMYT** | | | | | | | | | | | |
| Maize | | - | | - | | - | | - | | 54 | 46 |
| Wheat | | - | | - | | - | | - | | 57 | 43 |
| **Total** | | **-** | | **-** | | **-** | | **-** | **10,431** | **55** | **45** |
| **WARDA** | | | | | | | | | | | |
| **Total** | **790** | **(5%)** | **703** | **(4%)** | | **0** | **5** | **(0.03%)** | **2,732** | **19** | **81** |
| **ICARDA*** | | | | | | | | | | | |
| **Total** | **9,214** | **(8%)** | **8,336** | **(8%)** | **4,388** | **(4%)** | **15** | **(0.01%)** | **21,523** | **39** | **61** |
| **IITA** | | | | | | | | | | | |
| **Total** | **3,590** | **(9%)** | **2,319** | **(6%)** | **729** | **(2%)** | **16** | **(0.04%)** | **7,393** | **46** | **54** |
| **ICRISAT**** | | | | | | | | | | | |
| **Total** | | **-** | | **-** | | **-** | | **-** | **45,738** | **39** | **61** |
| **IRRI*** | | | | | | | | | | | |
| **Total** | **12,526** | **(16%)** | **2,982** | **(4%)** | **2,267** | **(3%)** | **99** | **(0.1%)** | **24,686** | **60** | **40** |
| **ILRI** | | | | | | | | | | | |
| **Total** | **1,008** | **(7%)** | **359** | **(3%)** | **67** | **(0.5%)** | **152** | **(1%)** | **2,666** | **58** | **42** |
| **INIBAP** | | | | | | | | | | | |
| **Total** | **12** | **(1%)** | **236** | **(23%)** | **124** | **(12%)** | | **0** | **-** | **-** | **-** |

No data were provided by CIP for distribution of accessions/samples inside the centre. For details of distribution outside the centre, refer to Table 7.1.

* Includes distributions inside the centre as well as to other centres; these may include duplicates.

** Includes distributions to private sector in both developing and developed countries; these may include duplicates.

*** Information on number of accessions distributed not available. For details of distribution outside the Centre, refer to Table 7.1.

**** Detailed information on distribution by accessions is not available. Figures given are based on number of samples distributed, adjusted for the total numbers of accessions distributed.

*Source*: SGRP Review of CGIAR Genebank Operations, 1996

**Americas** Levels of germplasm utilization from national collections vary widely in Latin America. In Cuba, germplasm utilization ranges from 50% of the potato and citrus fruits collections requested each year to only 5% for rice. Few other Caribbean countries have national genebanks. Average utilization of the Ecuadorian national genebank was reported to be 42%, with over 50% of requests coming from foreign institutions. Similarly, most requests to the Chilean germplasm banks come from foreign breeders. In Paraguay, it is estimated that only 5% of the accessions in public institutions are used every year. Both Canada and the United States have national germplasm collections and the annual distribution of accessions within each country is around 6% and 18% respectively.

### Use of PGRFA conserved in international genebanks

The distribution of accessions from the CGIAR Centre genebanks varies widely according to the destination and possible end-use of the material (Table 4.1). Most Centres distribute at least 10% of their total accessions annually — a rate which is higher than that for most national genebanks. From the information available, it is not possible to determine the total number of accessions distributed annually by each genebank, as the same accessions may be distributed to different recipients. In most centres there is much use of germplasm within the Centre itself — a reflection of the close link between IARC genebanks and on-site breeding programmes — or in other IARCs. Rates of distribution are particularly high for IRRI (rice 16%) and CIAT (*Phaseolus* 10%).

In some Centres a large proportion of accessions is also distributed to NARS mainly in developing countries, but also in developed countries. For example, INIBAP distributes 23% of its accessions to developing country NARS and 12% to NARS in developed countries. To a lesser extent, accessions are also distributed to the private sector.

It can also be seen from Table 4.1 that the number of samples distributed annually varies considerably between centres and between different crops in the same centre. For example, 82% of the samples of *Phaseolus* distributed by CIAT are for use within the centre, while 83% of cassava samples are distributed outside the centre. Similarly, only 19% of the samples distributed by WARDA are for use within the centre, while 60% of IRRI's distribution is in-house. For more details on distribution of samples outside the Centres, refer to Table 7.1 in Chapter Seven.

**Some conclusions about the distribution and use of germplasm**

The seemingly low figures for the proportion of genetic resources accessions in genebanks distributed to, or actually utilized in, crop improvement programmes must be interpreted with caution. The primary purpose of many base collections is long-term conservation, and, therefore, the rate of "utilization" may be expected to be low. In addition, the utilization of a relatively small part of a genebank's collection can lead to large benefits, proportionally far greater than the quantity of accessions used. A distinction must be made, therefore, between low rates of utilization and poor utilization.

Even given this relationship, however, there is a widespread view, expressed at numerous sub-regional meetings in preparation for the International Technical Conference, that the utilization potential of these plant genetic resources is not being fully realized. In particular, it has been noted in many regions covering developing countries that, while genetic resources from the region are widely used as inputs in plant improvement programmes around the world, utilization in the region of origin is poor.[12]

## 4.2.2 Constraints to germplasm use

In the Country Reports, the following major constraints to the utilization of germplasm in national genebanks were identified: lack of characterization and evaluation data (reported by 45 countries), lack of documentation and information (42 countries), poor coordination of policies at the national level (37 countries) and poor integration between genebanks and users of germplasm (32 countries).[13] The regional situation is described below:

**Europe**

The major constraint to utilization reported is the lack of characterization and evaluation data (53% of countries in Eastern Europe and 24% in Western Europe), lack of documentation and information (47% and 29% respectively), and lack of policy coordination (respectively, 41% and 18%).

**Near East**

Main constraints to utilization are reported to be lack of integration of the genebank with users (35% of countries), lack of characterization and evaluation data (35%) and lack of policy coordination (24%).

**Africa**

The most common constraint, reported by 29% of countries, is the lack of policy coordination, while 26% report the lack of integration between conservation and utilization programmes.

## Table 4.2 Obstacles to the greater use of PGFRA

| Obstacle | How it might be overcome |
|---|---|
| Lack of information on material existing *in situ* | • surveys and inventories |
| Bias in material conserved | • targeted collecting<br>• development of conservation methodologies for non- orthodox seeded and vegetatively propagated plants |
| Lack of evaluation/information about conserved material (*ex situ* or on-farm) | • documentation and characterization<br>• evaluation<br>• surveys of traditional knowledge<br>• crop networks |
| Lack of information about existence of conserved material | • information and communication systems<br>• crop networks |
| Difficulty in accessing collections | • rational organization of base, active and working collections<br>• legal arrangements<br>• greater collaboration between genebanks and breeders, *inter alia* through strong national programmes<br>• documentation and communication systems |
| Difficulty in handling large collections | • documentation systems<br>• core subsets<br>• crop networks |
| Difficulty and expense of introducing genetic diversity into breeders' adapted lines | • pre-breeding/genetic enhancement programmes, including base-broadening |
| Lack of plant breeding capacity | • increased funding and/or training<br>• international collaborative programmes |
| Unsuitability of improved varieties for marginal environments and/or specific needs of small farmers | • decentralized breeding, including participatory approaches |
| Lack of effective seed production and distribution networks for small farmers | • stimulation of privatesector and informal seed production and distribution networks |

> (continued) **Table 4.2 Obstacles to the greater use of PGFRA**

| Obstacle | How it might be overcome |
|---|---|
| Lack of availability of landraces for direct use | • evaluation *in situ* and *ex situ*<br>• provision of landraces by genebanks for multiplication and distribution to farmers |
| Unsustainable use of wild underutilized species | • development of sustainable management practices |
| Small range of species addressed | • improvement programmes for minor staples and other underutilized species |
| Restrictions on variety release, seed distribution | • review of regulatory framework |
| Lack of markets | • postharvest processing;<br>• promotion of new markets |

*Source:* Country Reports

Other constraints are lack of documentation and information on the accessions held and the absence of characterization and evaluation data.

**Asia and the Pacific**

Lack of characterization and evaluation data, documentation and insufficient integration between conservation and utilization programmes are the main constraints in this part of the world.

**Americas**

In general, lack of breeding programmes and domestic coordination policies, and poor documentation and characterization are considered the main obstacles to effective national utilization of Latin American plant genetic resources. Canada reports that utilization of its national collection could be improved with better integration of the genebank with users and better documentation and information, while the United States reports a need for more characterization and evaluation of accessions in its collection.

Constraints to the effective use of plant genetic resources were discussed at many of the sub-regional preparatory meetings for the International Technical Conference. Numerous constraints were identified. Some of these problems, together with possible ways of overcoming them are listed in Table 4.2.

The constraints may be summarized as follows:

- lack of proper coordination between genebank managers, breeders and other users;
- lack of adequate and useful information about conserved germplasm;
- the long-term nature of pre-breeding activities required to broaden the base of breeding materials;
- insufficient capacity for plant breeding and research in countries (lack of trained personnel, facilities and financial rewards);
- various problems affecting the diffusion of both traditional and new varieties.[14]

**Table 4.3 Extent of evaluation of country collections**

| Country | % Evaluated* |
|---|---|
| **Europe** | |
| Czech Republic | 60 |
| Poland | 68 |
| Slovakia | 28 |
| Ukraine | 90 |
| **Near East** | |
| Islamic Republic of Iran | 5 |
| Egypt | 15 |
| Morocco | 60 |
| **Americas** | |
| Colombia | 20 |
| Paraguay | 31 |
| **Africa** | |
| Guinea | 50 |
| Eritrea | 0 |
| Ethiopia | 100 |
| Seychelles | 90 |
| **Asia and Pacific** | |
| Bangladesh | 23 |
| Nepal | 28 |
| Thailand | 50 |
| Republic of Korea | 40 |
| Mongolia | 20 |

* Data are % of collection evaluated at least once, i.e. for one or more traits.

*Source:* Country Reports

National programmes on PGRFA have an important role to play in bringing conservers and users of PGRFA together, both at the national level and internationally (discussed in Chapter Five). Networks can ensure good communication between and within these groups at an international level. Crop networks are particularly important in facilitating the efficient sharing of evaluation data, and in guiding genetic enhancement programmes. (This is discussed in Chapter Six.)

The need to improve and review priorities for the various utilization activities — evaluation, pre-breeding, plant breeding and other crop improvement programmes, seed production and distribution, and marketing — is discussed in the next section.

## 4.3 REVIEW OF UTILIZATION ACTIVITIES

### 4.3.1 Evaluation of PGRFA

The evaluation of plant genetic resources provides information about the various useful traits of the conserved germplasm accessions which could facilitate their utilization by breeders, researchers and farmers.[15] It is a continuous on-going process. In a sense, breeding work itself is part of a larger process of germplasm evaluation. During the preparatory process, lack of useful evaluation information was pointed out as a major hindrance to the process of improving and increasing the utilization of PGRFA. Almost every country identified the need for greater effort in the evaluation of conserved germplasm.[16] Very little information, however, was provided in Country Reports on the state of evaluation of genebank collections. Only 55 Reports referred to the state of evaluation in their national collections, and the information that was provided varied widely in content.[17] Where percentages of the total collections which had been subject to some form of agronomic evaluation were cited, these were often low (Table 4.3).

The state of evaluation among the main collections of the International Agricultural Research Centres (IARCs) is, generally, better reported than that of other genebanks.[18] The evaluation status of some of the major mandate crops of the IARCs is given in Annex 2. Much of the evaluation work has been on resistance to pests and diseases. There is a need to increase the extent of evaluation of some of the more recently established CGIAR collections (e.g. INIBAP, WARDA). In general, most of the existing evaluation information about the IARC collections is not easily accessible. Many of the centres (IRRI, ICRISAT, CIAT) perform multi site evaluations of accessions for desirable characteristics in different agro-ecological regions.

There are a few examples of germplasm being systematically evaluated using a network approach, at either an international or national level. For instance, the International Network for the Genetic Evaluation of Rice (INGER), co-ordinated by IRRI, has been operating for 20 years and has contributed greatly to the increased use of rice germplasm. Similarly, INIBAP has developed the International Musa Testing Programme for the evaluation of banana and plantain germplasm in a number of locations. International testing programmes operate for the multilocational evaluation of elite germplasm of several other crops. This work is done primarily through NARS. Nineteen public-sector institutions and 21 private institutions are collaborating in the United States Germplasm Enhancement Maize project (GEM) which is using enhanced maize germplasm to broaden the genetic base of maize hybrids in the United States.[19] During the preparatory process, the following needs were identified with regard to germplasm evaluation.

### International collaboration

Evaluation is not a simple task and it cannot be accomplished efficiently by any one country, international centre or private organization alone; international collaboration is needed. Representatives to the South American sub-regional meeting, for example, recommended the establishment of an evaluation network for local varieties of important crops that could represent a significant comparative advantage for the countries of the region.[20] Kenya has indicated an interest in cooperation and coordination, both nationally and internationally, for the evaluation of PGRFA,[21] and Japan has proposed international collaboration to ensure that the world's 30 major crops are well evaluated.[22]

### Information and documentation

There is a lack of user-friendly documentation systems with standard formats to facilitate data exchange and the dissemination of information on characterization and evaluation to a wider audience of users.[23]

Arrangements are needed to ensure that evaluation data obtained through research by breeders are given to genebanks and other donors of germplasm, stored and made available to other users.[24] In addition, several countries have identified the need for increased collection and utilization of ethnobotanical and indigenous knowledge associated with PGRFA.[25] The development of core collections can provide users with improved access to collections as a result of the increased opportunity for detailed evaluation, better documentation and structured search strategies that can be developed (Box 4.1).[26]

### Box 4.1 Core collections

A core collection is a sub-set of an entire collection which represents, with a minimum of repetition, the genetic diversity of a crop species and its wild relatives.[27] A core collection may also be constituted to represent the diversity within the particular accessions of a species held in a particular genebank. It is claimed that over 70% of the total variation can be represented in a core that is about 10% of the size of the whole collection.[28] The sheer size of many collections is frequently cited as a barrier against their increased use.[29] Core collections are not intended to replace existing genebank collections, but to present the user with as much genetic diversity as possible in a smaller sub-set of samples.[30] Establishment of core collections is therefore in line with the interests of plant breeders, as these collections have fairly small numbers of accessions which are likely to possess the characters needed for their breeding programmes.[31] The core collection need not be assembled, put aside, or treated differently from the rest of the collection. It may be identified on paper and reconstituted as appropriate.

Examples of core collections include:

- an international crop network for barley that is developing a core collection for that crop;
- a Brazilian cassava core collection (in the course of developing this collection, the centres involved in maintaining or breeding cassava in Brazil gained much useful knowledge about their material, its origin and the degree of duplication within it);
- a core collection for *Phaseolus* based on a sophisticated agro-ecological classification of Latin America developed by CIAT;
- a core collection of peanut accessions in the United States, selected using the national Germplasm Resources Information Network (GRIN).

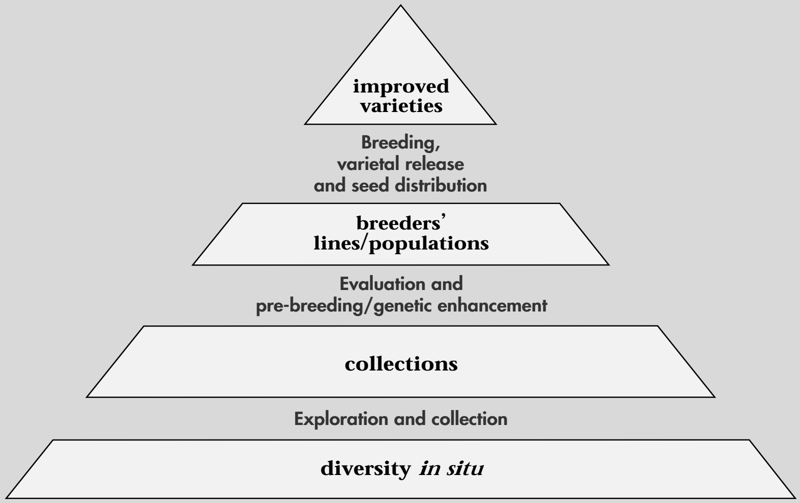
Suggested methods for applying the core concept to maize and coffee collections have also been published. The USDA is currently applying the core collection concept to most of its major crop species.

The need to establish core collections and develop methods for this purpose has been acknowledged during the preparatory process for the International Technical Conference.[32]

### Evaluation in relevant environments

For most traits which are environment-dependent, especially those which determine yield, evaluation must be undertaken in the appropriate environments, normally by breeders, farmers or other users of the germplasm. Germany has identified the need for more studies of genotype by environment interactions.[33] For some traits - for example, disease resistances - evaluation can be carried out systematically by specialists located at a genebank or research centre.[34]

### Box 4.2 The "breeders' diversity triangle"




This diagram represents the levels of diversity available for crop improvement. At the "apex" are improved varieties, including "elite" varieties. Below this are breeders' populations, which represent breeders' working material from which the improved varieties are bred.[35] Below this are "reserves" of genetic resources in collections and in the field. Note that:

- diversity is higher at the lower levels of the triangle; accessing this diversity is important to "broaden the base" of breeding programmes;
- the "accessibility" of genetic resources, in terms of ease of access for breeders, decreases as the triangle is descended; it can be difficult to introduce diversity from lower levels into breeding programmes without disrupting the careful balance of genes which have been produced through generations of selection.

With modification, this diagram could also apply to crop improvement by farmers. In this case, farmers often continuously improve crops through mass selection, so the distinction between the top two levels may not always be apparent.

#### Evaluation to facilitate direct use by farmers

As farmers are the ultimate users of the material, closer interaction with breeders, both initially and at more advanced stages of evaluation, could be useful.[36] The evaluation of landraces is also important in order to identify landraces which could be used directly by farmers.[37]

## 4.3.2 Pre-breeding (genetic enhancement)

Although originally based on landraces, most modern varieties and the populations with which breeders work consist of "elite" germplasm that has been carefully built up over periods of perhaps ten to 50 years of research. Such outstanding genotypes are easily disrupted by crosses with unimproved "exotic" germplasm from landraces. Moreover, many breeders find that even within a very narrow base, constant improvements can be made.[38] These factors provide a major disincentive for breeders to access other germplasm sources, that are, apart from a single specific trait or characteristic, agronomically inferior. Therefore, unless outside sources of germplasm are considered absolutely necessary, breeders will usually try to find new genetic material within their own breeding lines. Over the long term, this leads to a dependence on an increasingly narrow base of elite germplasm base for crop improvement (Box 4.2).

Breeders, in fact, prefer to use pre-bred materials containing desirable exotic traits in domesticated genetic backgrounds. Pre-breeding is the transfer of genes and gene combinations from unadapted sources into more usable breeding material. This process is also known as "germplasm enhancement".

Two distinct pre-breeding approaches can be used (see also Annex 1-3):

- The most common approach is when a single gene is transferred into the elite gene pool by *introgression*. Through repeated crosses to elite genotypes -so-called backcrossing - or by using biotechnological techniques, the desired gene is inserted into an acceptable "genetic background" which is well adapted to the intended agronomic environment.[39] Introgression has been used mostly for transferring major gene disease resistances, but some stress responses and quality traits have also been transferred.
- A less commonly used approach, called *incorporation*,[40] or base-broadening, is the large-scale development of locally adapted populations from unimproved germplasm stocks. Incorporation is more powerful than introgression for broadening the genetic base, but requires a commitment to a long-term programme using a population-oriented rather than a gene- or character-based approach.

Examples of the introgression of genes from landraces and wild relatives were given in Chapter One (Boxes 1.2 and 1.3). The incorporation approach has, in a number of cases, been very successfully used to improve crop productivity. Some "classic" examples are the adaptation of tropical maize germplasm to conditions in the southern maize-growing areas of the United States,[41] the incorporation of Ethiopian and Sudanese sorghum landrace germplasm into adapted Indian cultivars,[42] and the base broadening of the narrow European *Solanum tuberosum* gene pool using *Solanum andigenum* germplasm from South America.[43]

At present, pre-breeding of major crops outside the developed world is largely performed by the IARCs. However, because the IARC programmes are limited to their mandated crops, genetic enhancement of many other crops is the de facto responsibility of national programs. These needs are currently not always met. Very few Country Reports mentioned pre-breeding or genetic enhancement as a national breeding activity, though several indicated the need for such work.[44] Malaysia, for example, highlighted the need to broaden its genetic base of the major economic exotic crops such as rubber, oil-palm, pepper and cocoa.

Pre-breeding is often considered to be an activity at the interface between germplasm conservation and utilization. As a result, which sector — private or public — and who — curators or breeders — should be responsible for this activity is not clear. Generally, it is considered a pre-competitive activity which commercial breeders cannot afford in the short term. The sub-regional meeting for the Mediterranean recognized the need to broaden the base of breeding materials and the long-term nature of pre-breeding activities required for this purpose.[45] Many public research institutions and universities have done pre-breeding in the past, but with the withdrawal of public funding, pre-breeding activities have often been abandoned.[46]

The resulting scarcity of long-term research funds as well as the lack of academic recognition (through publication and research funding) have contributed to the neglect of pre-breeding activities. These problems have negative long-term implications for maintaining or increasing the level of utilization of germplasm stored in genebanks. This important problem needs to be addressed at multiple levels.[47]

The need for greater attention to pre-breeding programmes was highlighted during the preparatory process for the International Technical Conference.[48] Both the introgression and the incorporation approaches to genetic enhancement require international collaboration to facilitate greater use of global crop gene pools and ensure the efficiency of the programmes. There is also a need to strengthen crop specific networks which can assess the need for, and oversee, genetic enhancement programmes.

## 4.3.3 Plant breeding and other crop improvement programmes

### 4.3.3.1 National capacities in crop improvement

#### Types of crop improvement programmes

A country's ability to improve crops depends, to a great extent, on the availability of technical, human and financial resources. Different levels of plant breeding and biotechnology require different levels of financial and technological resources. Farmers practise mass selection techniques to improve their crops, while plant breeders and biotechnologists use more complex and expensive techniques (See Annex 1-3).

It is difficult to state, accurately, what the crop improvement capacity of a particular country is. Based on the information provided in the Country Reports, however, countries can be grouped into four categories that correspond to the different levels of development of crop improvement programmes (Appendix 1).[49]

- Countries without formal-sector crop improvement programmes. These include many of the Small Island Developing States and some of the smaller countries of sub-Saharan Africa, the majority of which do not have sufficient resources to develop crop improvement programmes.[50] In some of these cases, small populations do not justify the development of independent programmes and a sub-regional or regional approach might be considered.
- Countries with basic formal sector crop improvement programmes, predominantly in the public sector, including germplasm identification, introduction and evaluation programmes. These are found mostly in poorer countries, including parts of Africa and the Caribbean, and particularly where farmers rely mainly on vegetatively propagated crops. Although limited, such programmes are often efficient and able to meet the current needs of the majority of farmers.
- Countries with plant breeding programmes, predominantly in the public sector (including parastatal companies and universities), that carry out evaluation, enhancement and improvement of PGRFA through hybridization programmes using both local and introduced germplasm. Such programmes focus primarily on major crops and may be found in many countries of Eastern Europe, most of the Near East, several countries in Africa, in Central America, the smaller countries of South America and about half of the countries in Asia.
- Countries with well-developed formal sector breeding programmes which also have access to the use of sophisticated plant biotechnology. This type of programme, is found mainly in Europe, North America, East Asia, the larger countries of Latin America and a few other countries such as India, The Philippines, Kenya, and South Africa. In developed countries, there is often large private sector involvement. Among the developing countries with sophisticated programmes are China, with its hybrid rice programme, and Cuba, where biotechnology procedures are utilized in plant breeding programmes aimed at producing transgenic potato plants and artificial seeds of vegetatively propagated crops. (See Box 4.3 for examples of the use of biotechnology in crop improvement programmes.)

In addition, some developing countries have well developed programmes for just one, or a very small number of export crops. For example, Barbados hosts the West Indies Central Sugar Cane Breeding Station which is a major producer of improved sugar cane varieties for the Caribbean.

Developing countries differ widely in their capacity to use modern crop biotechnology. Larger countries, and those with more financial resources and personnel trained in plant genetic resources, including Argentina, Brazil, China, India, Mexico and the Republic of Korea, are becoming increasingly self-sufficient in the use of many biotechnological techniques (Box 4.3). Most developing countries have insufficient resources to build up their own research and development capacity, or invest in the latest technologies. A number of factors have been identified which limit the application of new biotechnologies in developing countries.[51] Among these is the fact that plant biotechnology cannot be developed and applied in isolation if it is to have a significant impact on agricultural productivity. Moreover, it is most successful when applied to disciplines such as plant breeding and plant pathology which are already well established and supported. Furthermore, related to these considerations, there is the need for modern expensive laboratories which require long-term funding commitments.

### Box 4.3 Use of new biotechnology for PGRFA in developing countries

The new biotechnologies offer promise and opportunities to many countries. It is important to realize, however, that the technologies must be applied to a resource, in this case PGRFA. Parallel and complementary investments in both the technologies and the resources will be needed if the full potential of either is to be realized.

**Near East** Biotechnological applications in most countries of West Asia and North Africa are currently limited to supporting traditional plant breeding. A few countries have established tissue culture facilities for the propagation of some crops, particularly date-palm, while others are in the process of establishing plant biotechnology infrastructure.[52] In Egypt, the Agricultural Genetic Engineering Research Institute, established in 1990, focuses on biotechnology applications for potato, rapeseed, cotton, faba bean and tomato. In Pakistan, seven plant biotechnology laboratories had been established by 1985, including one at the National Agricultural Research Centre in Islamabad.

**Africa** In 1989, plant biotechnology in sub-Saharan Africa was limited to rudimentary *in vitro* plant biotechnologies for 30 crops at 20 centres, and concentrated on export crops rather than food commodities.[53] Most countries in the region are in the initial stages of applying biotechnology to plant breeding. Universities in Kenya, Uganda, Ethiopia, the Sudan and Burundi have contributed significantly to the development and application of these technologies. For example, Kenya's Jomo Kenyatta University College is using biotechnology applications to develop banana varieties, and the University of Burundi is coordinating the African Biotechnology Network. Applications have mainly been for *in vitro* propagation and multiplication, disease elimination and indexing, and, in the case of Kenya, have been particularly successful for *Pyrethrum*, cassava, sweet potato, horticultural crops, coffee, tea and forestry species.[54] The Kenya Agricultural Research Institute and the University of Nairobi also have significant expertise in agricultural biotechnology.[55] Zimbabwe's agricultural biotechnology programme conducts research on maize, millet, sorghum, cassava, groundnuts and fruit trees, all crops which have special significance for small farmers.

### >(continued) Box 4.3 Use of new biotechnology for PGRFA in developing countries

**Asia and the Pacific** India's Biotechnology Action Plan supports research on oil-palm and biofertilizers. China possesses one of the world's largest research bases for plant tissue culture. The number of Chinese research units working on plant tissue culture is estimated at more than 1,000. In Thailand, the National Centre for Genetic Engineering and Biotechnology supports research in five affiliated laboratories on plant tissue culture, plant selection and germplasm conservation, pest control and rice. In Malaysia, the Palm-Oil, Rubber and Forest Research institutes focus on applying tissue culture to their mandate crops, while the Malaysian Agricultural Research and Development Institute (MARDI) conducts biotechnology research on rice, cocoa, vegetables, field crops and ornamentals. In 1985, Indonesia established three inter-university centres for biotechnology with loans from the World Bank totalling $23 million. The Centre for Agricultural Biotechnology at Bogor is conducting research on *Rhizobium* and *Mycorrhiza* inoculants, and tissue culture of potato and other crops. In 1979, The Philippines established the National Institute of Biotechnology and Applied Microbiology at the University of Los Banos which conducts research on nitrogen fixation, biofuel production plant diagnostics and plant cell culture for the production of high-value substances.[56] The Republic of Korea has earmarked $80 million to be spent between 1988 and 2001 on agricultural biotechnology.[57]

**Latin America and the Caribbean** In 1989, plant biotechnology work was being performed on 120 different plant species, ranging from one (Dominica, Honduras) to 45 (Mexico) species per country. The most studied were potato, sweet potato, cassava, bean, maize, citrus fruits, tomato, banana, cocoa and papaya. At that time, 20 countries and 88 institutions were using new biotechnologies with the number of institutions per country ranging from one (most countries) to over 20 (Argentina, Brazil).[58] In Colombia, the Biotechnology Institute at the Universidad Nacional conducts biotechnology research on developing virus-free potatoes, biofertilizers and bio-insecticides.

## Role of the public and private sectors in crop improvement programmes

In the past, plant breeding has had strong support from the public sector, however, in many countries this support is declining. Associated with this decline is the increase and consolidation of breeding and seed production in the private sector. However, in the current economic, political, regulatory and social environments around the world, commercial plant breeding alone cannot meet the global demands on plant breeding, and public sector investment or NGO involvement is required to raise levels of agricultural productivity in many regions of the world[59] . Most public sector support of research associated with crop improvement has been directed at public research institutions and universities. There is increasing private sector involvement in research institutions, however, focused especially on developing and marketing plant products close to the commercialization stage. Research and development requiring long-term funding commitments are still performed predominantly by public research institutions and universities.

Country Reports show that plant breeding is still conducted in most countries by government-funded programmes. In 33% of countries however, the private sector is also involved in plant breeding (Figure 4.1). Table 4.4 provides an indicative list of the world's 26 largest plant breeding and seed companies, as of 1992.[60] The regional situation is as follows:

**Public and private plant breeding programmes** (% of countries reporting)

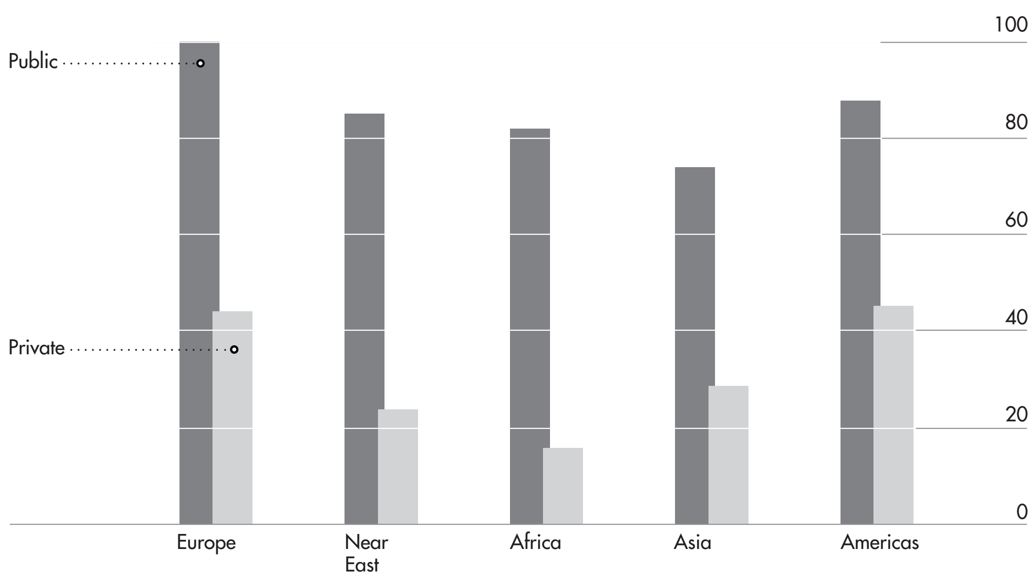



Figure 4.1 *Source:* Country Reports

**Europe** In Western Europe, although governments are involved in plant breeding, 59% of countries also report the existence of private plant breeding companies. Universities are reported to be involved in plant breeding activities in 41% of Western European countries. In reality, both figures are probably conservative. In Western Europe, the tendency is for government-funded breeding to be research-oriented with long-term objectives, and, increasingly, limited to pre-breeding, while the final production of new varieties is more and more the province of private breeding companies. In Eastern Europe, plant breeding is predominantly a government activity, and programmes are reported in every country which submitted a Country Report (17 countries). Private-sector involvement in plant breeding is only reported by four countries: Croatia, the Czech Republic (where private plant breeders receive support from the government), Slovakia and Ukraine. In the Russian Federation, private breeding companies are just beginning to emerge.

**Table 4.4 The world's largest private-sector seed companies**

| Company | Main activity | Head-quarters | Main subsidiaries | Seed turnover (mill. US$) | Core seed products |
|---|---|---|---|---|---|
| Pioneer Hi-Bred | Seeds | United States | | 1,500 | Maize, oilseeds, alfalfa, cereals |
| Novartis Seeds | Chemistry | Switzerland | NK (Northrup King), Hilleshög, S&G (Sluis and Groot), Rogers | 900 | Maize, oilseeds, sugar beet, vegetables, ornamentals |
| Limagrain | Seeds | France | Force Limagrain, Maïs Angevin, Nickerson, Vilmorin, Tézier, Clause, Oxadis, Ferry Morse, Harris Moran | 650 | Maize, oilseeds, cereals, vegetables, ornamentals |
| Advanta | Chemistry food industry. | Netherlands | Van der Have, Zeneca Seeds, SES | 460 | Maize, forage crops, sugar beet, cereals, oilseeds |
| Takii | Seeds | Japan | | 430 | Vegetables, ornamentals |
| Sakata | Seeds | Japan | | 390 | Vegetables, ornamentals |
| Seminis | Seeds | United States | Petoseed, Royal Sluis, Bruinsma | 375 | Vegetables |
| KWS | Seeds | Germany | Betaseed, Great Lakes Hybrids, Lochow Petkus, Semillas Seleccionadas, Betamag | 345 | Sugar beet, cereals, maize, forage crops, oilseeds, protein crops |
| Dekalb | Seeds | United States | | 250 | Maize, oilseeds |
| Cargill | agric. Trade | United States | | 250 | Maize, oilseeds, cereals, alfalfa |
| Monsanto | Chemistry | United States | Asgrow, Calgene, Hybritech, Holden Foundation Seeds | 200 | Maize, oilseeds, cotton, vegetables |
| Pennington | Seeds | United States | | 180 | Forage crops, turf |

> *(continued)* **Table 4.4 The world's largest private-sector seed companies**

| Company | Main activity | Head quarters | Main subsidiaries | Seed turnover (mill. US$) | Core seed products |
|---|---|---|---|---|---|
| Ball | Seeds | United States | | 180 | Ornamentals |
| Pau Euralis | Seeds | France | Rustica Prograin Génétique | 175 | Maize, oilseeds |
| Sigma | agric. Trade | France | Semences de France, Ringot, Serasem | 160 | Cereals, protein crops, maize, oilseeds, forage crops, turf, sugar beet |
| Saatenunion | Seeds | Germany | | 155 | Cereals, maize, oilseeds, forage crops |
| RAGT | agric. Trade | France | Semillas Monzon, Joordens Zaaden | 140 | Maize, oilseeds, forage crops, cereals |
| Svalöf/ Weibull | Seeds | Sweden | Semundo, New Field Seed | 140 | Sugar beet, cereals, maize, oilseeds |
| CEBECO | agric. Trade | Netherlands | Procosem, International Seeds, Seed Innovations, Van Engelen, Wiboltt, la Maison des Gazons | 140 | Protein crops, maize, oilseeds, cereals, forage crops, turf, vegetables |
| Mycogen | Biotech. | United States | | 140 | Maize, oilseeds, alfalfa |
| DLF | Seeds | Denmark | | 135 | Forage crops, sugar beet, oilseeds |
| Barenbrug | Seeds | Netherlands | New Zealand Agriseeds | 130 | Forage crops, turf |
| Maïsadour | agric. Trade | France | Orsem, Interdor, Agrar Semillas | 100 | Maize, oilseeds |
| **Total** | | | | **7,525** | |

Estimations are for 1996, based on annual reports, press releases and other information and are susceptible to change according to exchange rates and other factors.

*Source:* International Seed Trade Federation (FIS)

**Near East** Plant breeding in West Asia and North Africa is conducted mainly by the public sector, although private companies are involved in Morocco, Pakistan, Israel, Turkey and Jordan. Plant breeding is particularly important to the economy of Israel. In Central Asia plant breeding activities are carried out in the public sector, mainly in research institutions or experimental stations.

**Africa** In every country with a plant breeding programme, activities are funded by the government. In addition, in some countries there are private (often foreign) companies who are also involved, such as in Ethiopia, Kenya, Madagascar, Malawi, Mozambique and Nigeria. Universities are involved in breeding activities in several countries, and nine countries report receiving support from donors and non-governmental organizations.[61]

In **Asia and the Pacific**, plant breeding is generally conducted by governments, although in some countries in East and Southeast Asia, local and foreign private companies are also involved. NGO involvement in plant breeding is reported in The Philippines. Universities are involved in Malaysia, India, Pakistan, The Philippines and Japan, among others.

In **Latin America**, the public sector dominates most plant breeding activities. Exceptions are Argentina and Chile, where both the private and the public sectors play important roles. Much of the private breeding activity is concerned with the export of crops or seeds. Such activity includes research on crops such as cotton (Colombia), sugar cane (Colombia), oil-palm (Costa Rica), banana (Honduras) and black pepper (Honduras). In Chile, there are 12 foreign companies producing seed exclusively for export.

**Reported constraints to plant breeding activities** (% of countries)

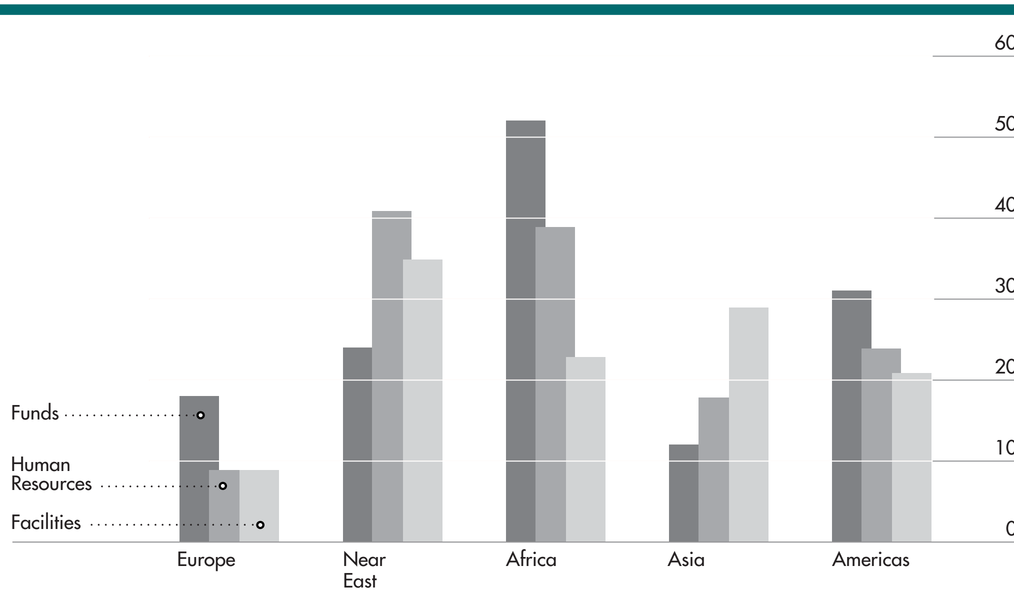



Figure 4.2 *Source:* Country Reports

### Constraints to plant breeding programmes

The major constraints identified in the Country Reports are shortages of funds (reported by 29% of countries), scarcity of trained personnel (25%), and a lack of suitable facilities (18%) (Figure 4.2).

In Eastern Europe the main constraint is funding (29% of countries). In recent years, the reduction in funding for government research in many Western European countries has resulted in cut-backs in pre-breeding and breeding-related research there. Shortage of funds is a particular problem in Africa (cited by 52% of reporting countries), while the main constraint to plant breeding throughout the Near East is the shortage of trained personnel (41% of countries). In the Asia and the Pacific, the shortages of trained personnel and facilities are regarded as the most significant constraints. Most Latin American countries agree that the lack of trained personnel and facilities are major constraints to plant breeding. Many countries, including Bolivia, Colombia, Costa Rica, Ecuador, Guatemala and Honduras, also believe that current plant breeding activities are unable to meet national needs.

### 4.3.3.2 Scope of crop improvement programmes

The International Agricultural Research Centres (IARCs) have well developed crop improvement programmes for their mandate crops (see Chapter Six), upon which they work in partnership with national agricultural research systems (NARS). The IARCs account, however, for only a small percentage of public spending on agricultural research by and for developing countries (4.3% between 1981-1985). Most countries have NARS and it is estimated that two thirds of the agricultural researchers in developing countries are engaged in work related to crops. In 1994, however, 95 out of 130 NARS in developing countries employed fewer than 200 researchers, while 39 NARS employed fewer than 25 researchers. Only 14 employed more than 1,000 researchers.[62] The crop focus of many of these NARS varies widely. The regional situation with regard to crop improvement programmes in developing countries is described below:

**Near East** Pakistan has developed and released rice varieties that now occupy 95% of the country's rice area. These varieties have helped to increase yields and enhance rice exports. Egypt, Morocco, Tunisia, Turkey and the Islamic Republic of Iran also have successful breeding programmes.

**Africa** National programmes in East Africa, particularly Kenya, Ethiopia and Uganda, have developed successful varieties of food crops that are being widely used nationally and throughout the region. These include Katumani maize, Serere composite (sorghum) and hybrid varieties of maize and other cereals. The greatest success story is perhaps that of "K20", the first bean variety developed entirely in eastern Africa, using the best local bean material and a Colombian landrace. The variety was developed in Uganda in 1968 and today K20 is the most widely grown bean variety in the sub-region, and perhaps on the entire continent. Surveys indicate that 56% of the more than 500,000 ha of beans grown in Kenya and 40% of the 400,000 ha in Uganda are K20, representing 16% of the total bean area in sub-Saharan Africa.[63]

Similarly in West and Central Africa, the exploitation of plant genetic resources has had a significant impact on the region's agriculture. The following species have benefited from improvement programmes:[64]

- millet, sorghum and maize, with the development of more productive varieties for rain-fed cultivation in the countries of the Sahel;
- cowpea, with the development of varieties insensitive to photoperiod and tolerant of the major diseases of the subregion;
- cassava, with the development of more productive varieties tolerant of bacterial diseases and mosaic virus, which limit production in the area;
- soybean - the development of several varieties adapted to savannah areas has facilitated this crop's introduction in Nigeria, Burkina Faso, Ghana, Guinea, Gambia and Senegal;
- rice - the results obtained with upland rice have made it possible to develop this crop in difficult regions, particularly those with soil salinity problems;
- coffee, cocoa, rubber, oil-palm and cotton - the quantitative and qualitative benefits of improved varieties are appreciable. Products derived from these species are highly valued on the world market, making them a significant source of foreign exchange.

Many countries, nevertheless, indicate that there are species of national importance which receive little investment in terms of conservation or improvement, including many locally important minor staples. For example, there are only very limited crop improvement programmes for yam in West Africa, even though it is of great importance as a food crop in the sub-region. Other important but neglected staple foods of West Africa include the minor millets, fonios, African rice and some legumes such as bambara groundnut. Côte d'Ivoire, Ghana and Nigeria are giving priority to major export crops such as rubber, coffee, cocoa and oil-palm.[65]

The balance between the use of local versus introduced germplasm by crop improvement programmes varies widely from country to country, depending on factors such as breeding capacity, available technological and plant genetic resources, the focus of individual crop improvement programmes and the agricultural needs of the country. A number of countries, including Botswana, Ethiopia, and the Niger, report that their breeding programmes focus particularly on the use of local germplasm, while others, such as Mauritius and South Africa, report that programmes are based primarily on introduced material.[66]

**Asia and the Pacific** In India, about 400 improved rice cultivars have been released through selections from landraces. Landraces have also been used to develop cultivars of wheat, maize, pearl millet, oilseeds (rape seed, mustard, linseed), pulses (Bengal gram, pigeon pea, green gram and field pea), vegetables (onion, bottle gourd, sponge gourd, chilis, cassava, sweet potato and potato), under-utilized crops (grain amaranth, buckwheat and rice bean), commercial crops (sugar cane, tobacco, black pepper, cotton, coffee and tea), spices (black pepper, turmeric) and multipurpose trees. The success of the Indian agricultural system is attributed mainly to its strong national research system, and to networking coordinated by the Indian Council of Agricultural Research.

Most of the major crops, including rice, maize, millet, oilseeds and pulses, have benefited from the use of Indian germplasm collections. About two-thirds of oilseed and pulse varieties are direct selections from local germplasm. These varieties are well adapted and are popular with farmers.[67] The Philippines also has extensive breeding programmes for maize, sweet potatoes, cassava, cotton, mung bean, peanut, cowpea, soybean, pineapple, papaya, mango, banana, squash, bitter gourd, sponge gourd, potatoes and peas.[68]

In Bangladesh, most of the plant genetic resources for commercial use are derived from indigenous sources, either as direct varieties or through varietal development programmes. For example, landraces contributed directly to 23 of 62 rice varieties, 20 of 23 jute varieties and about 90% of all leafy vegetable varieties.[69]

In the Pacific, activities include a coordinated breeding programme and variety testing of superior clones for taro and sweet potato in the countries of the subregion. For taro, collaborative work is conducted on the identification of parents and progeny, testing for resistance to taro leaf blight and acceptable eating quality. For other crops, the main activity is adaptability testing of introduced germplasm.[70]

**Americas** Apart from the countries of the Southern Cone which have strong breeding programmes for wheat and other temperate crops from the Old World, most countries focus on crops whose centre of origin and diversity is in the Americas. The extent to which native germplasm is used varies. In Ecuador, most of the current cultivars of potato, maize, bean and barley are exclusively based on Ecuadorian germplasm. In Bolivia, some cultivars of potato, maize, quinoa and faba bean that are based on Bolivian germplasm have been released. Most of the improved varieties in Peru are of national origin. Enhancement of local rice cultivars in the Dominican Republic has produced a series of rice cultivars which are widely planted. In Venezuela, 30% of the germplasm used in the development of new maize varieties is native. The main aim of Colombian and El Salvadoran plant breeding programmes is the adaptation of imported germplasm to local needs. On the other hand, the Mexican programme, which uses both foreign and native material, aims to adapt imported varieties and enhance landraces. Most Mexican farmers who grow maize, wheat, beans and rice use local varieties, while 90% of the export vegetable acreage is planted to modern varieties. There is a high level of interdependency within the region with respect to genetic resources from both the IARCs (CIAT, CIP, CIMMYT) and other genebanks in the region. For instance, 90% of Argentinean wheat cultivars use Mexican germplasm.

Within the region, there are national breeding programmes for maize (11 countries), wheat (7), potato (9), rice (9), soybean (6), beans (6), sweet potato (5), sorghum (5), fodder crops (4), sugar cane (3), cassava (3), legumes (3), citrus fruits (3), coffee (2), cotton (2), peppers (2), sunflower (2), peanut (2), barley (2) and banana (2). Other crops for which the Country Reports cited plant breeding programmes are cocoa (Ecuador, Cuba), coffee (Cuba), eucalyptus (Uruguay), faba bean (Bolivia), grape (Chile), lentils (Chile), oil-palm (Ecuador), peanut (Bolivia), quinoa (Bolivia), tobacco (Cuba), tomato (Panama) and sesame (Peru). Argentina, Bolivia, Cuba, Dominican Republic, Ecuador and Venezuela have specific breeding programmes for export crops such as cocoa, coffee, cotton and banana.

In general, there is little investment in minor crops and under-utilized species as compared to the commercially more important crops. Only a few countries, such as Ecuador and Peru, are making particular efforts to establish national breeding programmes for native Andean crops. For instance, in Ecuador, all the current advanced cultivars of quinoa, amaranths, melloco, oca and zanahoria blanca have been developed with native plant genetic resources. Most of the other national breeding programmes do not handle minor native crops.

### Crop coverage

At the global level, most of the world's major staple crops are well served by crop improvement programmes. International crop improvement efforts have delivered spectacular production increases, especially for crops such as wheat, maize and rice. These crops received particular attention during the green revolution and continue to be the focus of major improvement efforts in both developed and developing countries. For instance, a 1993 CIMMYT survey identified more than 1,150 scientists[71] performing wheat improvement research in developing countries with a total annual expenditure of US ò100 million.[72] Yet even for these crops there is still need for improvement, particularly for the less favourable environments.

The private sector tends to focus on crops that either cover large areas (maize, soybean, wheat, rice) or that generate high per hectare income (tomatoes, sugar beet, etc.). It also tends to concentrate on those crops that offer the strongest intellectual property protection, either through legislation or more often through the "natural" means afforded by hybrids.

This indicates a continuing need for public investment in plant breeding to cover the gaps in private-sector efforts. Table 4.1 indicates that the world's largest breeding and seed companies concentrate on predominantly commercial crops and crop groups such as maize, wheat, soybeans, horticultural plants, oilseed crops, sugar beet, forages, sunflowers, cereals, potatoes and small grain cereals.

There is, therefore, a need for public-sector funding of improvement programmes for other staple crops (e.g millets, cassava, sweet potato, plantains) where there is less commercial incentive due to the lack of "effective demand". Far less resources are therefore invested in such food crops, which are sometimes described as "orphan crops",[73] though they include many food and export crops which are important to developing countries.

Even less research and very few breeding programmes exist for the under-utilized species, despite the fact that many are used daily, contribute to healthy and balanced diets, and offer farmers opportunities for agricultural diversification and additional income.[74] Many countries have stressed the need for increased breeding and research on under-utilized species, and for domesticating many wild and semi-domesticated food plants. Recommendations to this effect were agreed upon at several sub-regional meetings held in preparation for the International Technical Conference.[75] Public-sector improvement programmes are needed for these crops as there is little commercial incentive to conduct improvement programmes on them and few resources have been used to improve under-utilized crops.

Many of these minor and under-utilized crops fall outside the current mandates of the International Agricultural Research Centres. During the preparatory process, it was suggested that particular attention should be given to such species, and that perhaps the mandate of the IARCs should be broadened to include a wider range of crops.[76] Existing IARC programmes for developing other species include the forage programme of the Centro Internacional de Agricultura Tropical (CIAT), the Andean Root and Tuber Crops Programme of the Centro Internacional de la Papa (CIP), research on several multipurpose tree species by the International Center for Research in Agroforestry (ICRAF), research on several pasture and forage species by the International Livestock Research Institute (ILRI) and the work of the new Centre for International Forestry Research (CIFOR).

The countries of East, Central and West Asia, the Mediterranean, and South America also highlighted the need to give more attention to the PGRFA of forests, rangelands, drylands and other marginalized environments and, in particular, to pasture species. The importance of developing under-utilized stress-tolerant plants and promoting the use of medicinal plants, were also mentioned.[77]

The countries of South America, and West and Central Africa, stated that their respective regions have comparative advantages with respect to their indigenous crops, but because little attention is given to such crops, they remain under-researched.[78] Paradoxically some of these "neglected" crops may actually be "over-exploited" due to the lack of sustainable management plans in the face of high population pressure. It has been proposed that inventories of under-utilized species be drawn up.[79]

Other sub-regions also identified the need for inventories. At the European meeting, it was proposed that, as a first step, an inventory of under-utilized species in Europe be established with the following information:

- a list of under-utilized species, their distribution throughout the region and the level of utilization at the local or sub-regional level;
- the availability status of germplasm in genebank collections;
- an indication of the level of genetic erosion of the species;
- a list of institutions and experts working on the species;
- a list of ongoing activities on these species;
- a list of relevant publications.

The following more specific needs were identified to promote the utilization of under-utilized species:[80]

- collaboration with local populations to improve understanding of underutilized species and their sustainable management;
- research toward better management of under-utilized species;
- research and development of methods of propagation or domestication in order to generate income and avoid the overexploitation of wild plants;
- use of botanical gardens and genebanks for conservation;
- promotion of information exchanges and publications;
- improving post-harvest processing to increase consumption; and
- development of markets for products from under-utilized species (see section 4.3.5).

Major international lending institutions (e.g. the World Bank and the Inter American Development Bank) are now encouraging non-traditional agricultural exports (NTAEs) as a means of reducing poverty, increasing income and diversifying risk, particularly in Latin American and many African nations.[81] NTAEs are intended to promote the export of labour-intensive agricultural crops that are non-traditional. The crops concerned vary from country to country, but may include winter vegetables, nuts, exotic tropical fruits and ornamental plants and flowers. NTAEs are considered a key to economic growth because of the high value added through processing and their ability to command high prices at a time when prices for other products stagnate or decline. Concentration on non-indigenous crops, however, can create a dependency on expertise and technologies from outside the country as well as weakening the country's comparative advantage in terms of its germplasm.

#### 4.3.3.3 Strategies of crop improvement programmes

An impressive range of new plant varieties of many crops have been released from plant breeding programmes which have contributed to large yield increases in many parts of the world. About 50% of the increase in production of "Green Revolution" rice and wheat has been ascribed to the breeding of new varieties, the remainder is derived from fertilizers, pesticides, fungicides and improved crop management.[82] Over the last 25 years, irrigated rice production has increased by 3% per year; over half of this growth may be attributed to breeding.[83] Between 1930 and 1990, global yields of maize and sorghum increased by 471% and 455%, respectively. In addition, new crop varieties which incorporate resistances to pests and diseases have contributed to the development of sustainable agricultural systems around the world by decreasing reliance on pesticides.

Regionally, however, the success of modern plant breeding has been uneven. African farmers, for example, have on the whole, benefited less from the Green Revolution than farmers in Asia and Latin America. This is in part due to differences between crops: yield increases have been high for wheat and rice, and, to a lesser extent, maize and less significant for sorghum, pulses and roots and tubers which are grown in Africa mainly by small- and medium-scale farmers. The increases in yields in Africa, however, have not been as high as those for Asia,[84] even for wheat, rice and maize. For other staple crops (e.g millets, cassava, sweet potato, plantains) yield gains have tended to be lowest in the very regions where they are most important for food security (see Figure 1.3 and Annex 2).

In many parts of the world, particularly in physically or economically marginal environments, modern plant breeding has had little success in producing varieties which meet farmers' needs. There are, however, fewer scientists concentrating on resource-poor farming systems in marginal areas as compared to agricultural systems in high-potential areas.[85] The FAO Commission on Plant Genetic Resources has indeed noted the importance of improving the use of genetic resources to promote sustainable agriculture in marginal areas.[86]

Agricultural production in all regions around the world ranges from high-potential to marginal areas.[87] Agricultural policies necessarily differ accordingly: production must be as high and competitive as possible in the high-input high-potential areas. Marginal areas call for a more subtle and varied approach, as the aims are multiple. Increasing food production is certainly a primary concern, but maintaining rural populations on the land and preventing any further degradation of land that is already marginal are important policy considerations as well.

It is increasingly recognized that different areas require different approaches to the utilization of plant genetic resources. While high-yielding varieties, including pure lines and F1 hybrids, may be most appropriate in high-potential areas, the greater use of landraces or improved local varieties, or material from crosses of landraces and improved varieties, may be more appropriate in marginal areas.[88] For example, in several countries in East Africa, Ethiopia, Eritrea, Burundi and Uganda, most food production is still heavily dependent on traditional varieties and farming systems. This is due to the difficulties in developing varieties that are compatible with the diverse traditional agricultural practices and complex agro-ecological environments. While well-defined crop-specific programmes for evaluation, enhancement and improvement exist, particularly for such crops as maize, beans, oil crops, sorghum, millet, wheat, barley, banana, forages, teff and pulses, in general, plant breeding efforts in the region have tended to favour the commercial and semi-commercial sectors and subsistence farmers who no longer practice traditional agriculture.[89]

Two complementary strategies for agricultural research and development have now been identified.[90] Many past successes in research were due to the concentration on high-potential areas (often irrigated or subjected to a high level of inputs) and generic technologies with widespread applications (for example the high-yielding varieties of wheat and rice developed through breeding for *wide adaptation*). An expert panel appointed by CGIAR to develop a "vision" for international agricultural research states that this research strategy must continue, though with more concern for the environment, in order to meet the demands of increasing populations, particularly in urban areas.[91] However, the panel also concluded that a second paradigm of agricultural research is required to meet the needs of the majority of the rural poor who live in areas that have fewer natural resources, are prone to natural disasters, and who are far less able to purchase inputs such as fertilizers and pesticides. This second type of research is more complex, based on strategies aimed at farming systems rather than particular crops and less reliance on external inputs. It requires greater use of genetic diversity, including approaches to plant breeding which can make use of *specific adaptation* (Box 4.4). This new research also requires greater involvement of farmers and local communities.

### Box 4.4 Breeding for wide and specific adaptation

**Wide adaptation approach**

Typically, the purpose of a breeding programme is to select the genotypes with the highest yield potential, i.e. a superior physiological ability to produce yield. This is most easily done when growth is not limited by pests, diseases and weeds or the lack of water and nutrients, i.e., in an environment offering optimal crop conditions.[92] The high-yielding selections are then tested in different locations for a number of years in order to select the varieties with the most stable performance under different conditions. This breeding strategy was pioneered during the early 1960s at CIMMYT and with maize breeding in the United States. Through the Green Revolution, this approach came to have a profound influence and success. Its merits have been documented with numerous crops which, as a result, have higher yields and stress tolerance.[93]

**Specific adaptation approach**

It has become increasingly apparent, however, that the wide adaptation scheme also has some shortcomings. The tendency to genetic vulnerability has already been mentioned. The limitations of the Green Revolution in more marginal areas, where farmers' traditional cultivars often actually compete very well, is another. Such cases of "*genotype x environment interaction"* indicate that different genotypes will be superior in different environments. These environments may require different breeding approaches aimed at exploiting rather than avoiding genotype by environment interaction. Breeding plants able to cope with environmental stresses has primacy over yield potential under such circumstances, though it is related to and should increase average yields over time. Hence, the most efficient selection of these genotypes is done *in* a particular environment not *for* it. The results of ICARDA's programme demonstrate the usefulness of this specific adaptation strategy. Fitting cultivars to an environment rather than the other way around is especially relevant where inputs are unavailable, too expensive or unprofitable due to a stressful and unpredictable environment.

The CGIAR expert panel concluded: "while the first Green Revolution took as its starting point the biological challenge inherent in producing new high-yielding food crops and then looked to determine how the benefits could reach the poor, [a] new revolution has to reverse the chain of logic, starting with the socio-economic demands of poor households and then seeking to identify the appropriate research priorities."[94] In order to maximize the contribution of genetic resources, researchers in CGIAR and elsewhere are looking increasingly at participatory approaches to plant breeding.

#### Participatory plant breeding

Currently, most farmer participation is limited to goal-setting through surveys of farmers' needs, priorities and constraints and through farmer representation at research advisory committee meetings (e.g., in Kenya, Uganda and the Sudan)[95] and evaluating varieties at on-station and on-farm research trials. Most breeding programmes in Latin America report minimal participation by farmers except for some in Cuba, the Dominican Republic, Guatemala and El Salvador.[96] According to reports from other countries, farmers are involved in the evaluation of new varieties in 29% of countries, ranging from 52% in Africa to 15% in Europe. Participation of farmers is rarely extended to other stages of plant breeding. Recently, however, a number of participatory plant breeding projects have been undertaken in developing countries. The examples below indicate a range of possible approaches (further examples are provided in Annex 1-3).

- In the ICRISAT pigeon pea breeding programme for resistance to insect pests, entomologists worked closely with women farmers in on-farm trials in drought-prone marginal environments in Andhra Pradesh (India). Participatory Rural Appraisal methods allowed farmers to compare improved pest-resistant pigeon pea (ICRISAT material) with their local varieties, using their own evaluation criteria. The parameters considered by the women farmers went well beyond the conventional yield and pest resistance measurements used by most scientists and variety release schemes.[97]
- Ethiopia's Biodiversity Institute has a programme for restoring displaced farmer varieties and introducing appropriate landrace materials into various agroecological zones and farming communities. The programme incorporates the enhancement and improvement of farmers' varieties of barley, durum wheat and teff. The farmers are fully involved at all levels of varietal development. This strategy is in the process of being institutionalized through the National Plant Genetic Resources Policy.[98]
- In the CIAT bean programme in Rwanda,[99] expert farmers (i.e. superior seed selectors) evaluated selections with breeders under on-farm conditions. Results showed that farmers and breeders differed in their evaluations; farmers

selected traits that would be suitable under specific conditions and in mixtures. As a result of the farmers' involvement, some of the selected genotypes were very quickly adopted, unlike on previous occasions.

- In a participatory rice breeding programme in Sierra Leone, part of the worldwide Community Biodiversity Development and Conservation Programme, local farmers and rice breeders from the Rokpur Rice Research Centre work together to select superior rice varieties on-farm. This approach is expected to make improved varieties available to farmers much more quickly than with conventional approaches, and it has been suggested that this programme be used as a model for others.[100]

Breeders and farmers both have comparative advantages which help define the role each assumes in participatory plant breeding.[101] Breeders have access to a wide range of genetic diversity as well as the scientific knowledge and methods to work efficiently on the development of improved germplasm. Farmers can be good at selecting material which suits their particular environments and resource levels. Farmers also understand the qualities consumers will look for. To be able to work together, plant breeders and the institutions for which they work will have to become more sensitive to the capabilities of farmers and the actual and potential contribution they can make to the breeding process (see Annex 1-3).

The need to rethink conventional breeding strategies and promote farmer participation, especially for the improvement of landraces, was identified at many sub-regional meetings.[102] Suitable participatory plant breeding methodologies are required[103] and the experience of the Community Biodiversity Development and Conservation Programme was suggested as a model.[104] Decentralization of formal plant breeding programmes to specific agroecological areas and farming communities could help support these activities.[105]

Participatory plant breeding may increase the chances of breeding successes in the complex farming systems of these diverse and marginal environments. It may also contribute to the wider use of genetic diversity and increase the maintenance and development of locally adapted genetic resources. It may also speed up the process of making new varieties available.[106] Finally, participatory approaches to plant breeding could help build a foundation for growth in productivity and prosperity which could then provide a basis from which to attract investment from the private commercial sector.[107]

Some of the possible advantages and disadvantages of participatory plant breeding approaches are further discussed in Annex 1-3.

### 4.3.4 Seed supply programmes

The scope of the formal seed industry is limited in developing countries, where less than one tenth of the farmers use the formal seed sector as their primary source of seed. Retention from their own harvests and farmer to farmer seed exchanges are still the most common sources of seed in almost all developing countries and are common as well in many developed countries.[108] Given the informal nature of these activities, Country Reports were unable to provide much information on the extent of activity in this sector or on needs. As far as the formal seed sector is concerned, seed production and distribution in developing countries are predominantly carried out by the public sector, whereas the private sector dominates major crops in Europe and North America. Involvement of the private sector in seed activities is reported in 30% of Country Reports. The balance between public and private involvement in the formal seed sector in developing countries is currently changing in favour of the private sector.[109] The regional situation is described below.

**Europe** In Eastern Europe, seed production and distribution is problematic where economies are in transition from centrally planned to market systems. In many cases, the public system is no longer operating, but a new private sector has not yet emerged either. In Western Europe, the seed sector is generally well developed and in some countries, such as the Netherlands, it is an important national industry. In general, this is a private-sector activity, although the public sector may also be involved, particularly with less profitable crops. One problem related to the predominance of private seed companies is reported to be the lack of varieties adapted to specific environmental conditions.[110]

**Near East** Formal seed production and distribution are carried out for the most part by the public sector, but private companies are also involved in Israel, Turkey, Jordan, Morocco, Tunisia, Lebanon and Pakistan. In several of the countries of the former Soviet Union, the private sector is starting to develop, but, at present, seed distribution generally does not meet national needs. Recently, there has been some investment by the World Bank in the seed industry in Uzbekistan.

**Africa** Formal seed production and distribution in Africa are generally a government activity. Private sector involvement in the industry is reported only in Kenya, South Africa, Uganda, Malawi, Sierra Leone, Zambia, the United Republic of Tanzania and Zimbabwe, though retail sales by companies are certainly taking place to some extent in many other countries. The private sector, however, is becoming more involved in horticultural and hybrid seed production.[111] In Tanzania, the private sector is only involved in testing new varieties which have been developed outside the country.[112] While many African countries received substantial bilateral and multilateral donor assistance in the past, only one country, Sierra Leone, reported the existence of an aid project on seed production - one funded by the German Ministry for Economic Cooperation and Development (BMZ) handled through the German aid agency (GTZ).

**Asia and the Pacific** Seed distribution in Asia is carried out mainly by the public sector, but private companies operate in some countries such as, for example, The Philippines, where hybrid maize seed is distributed by a private company. The private sector is becoming more involved in horticultural and hybrid seed production here as well.[113] Seed production systems need improvement; 41% of the countries report the inability of the seed sector to meet national requirements. This includes China, where, it is reported, reform of the seed production system is urgently required, and India which has recently opened its doors to foreign seed companies.

**Public- and private-sector seed systems** (% of countries reporting)

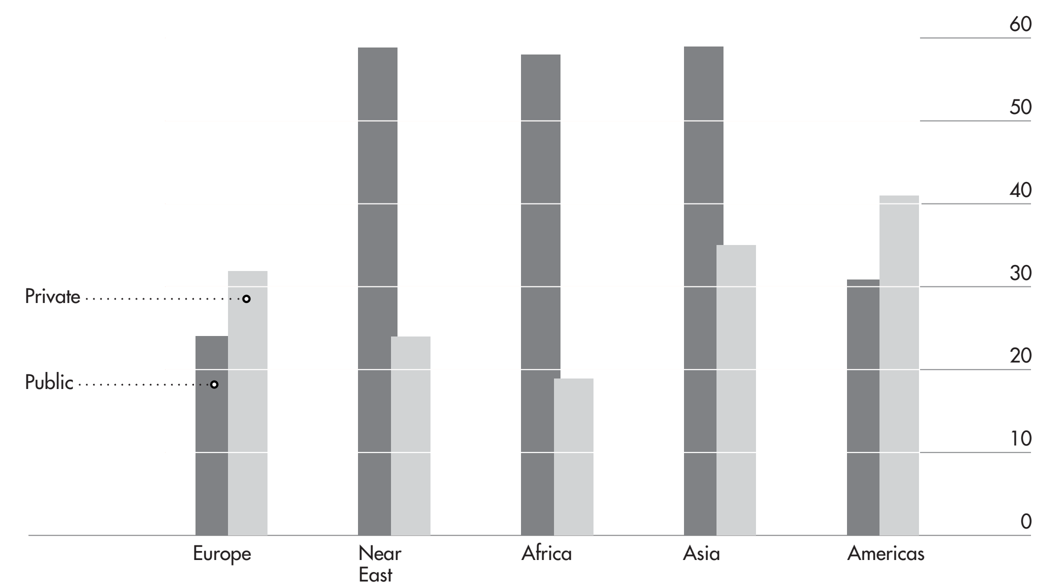



Figure 4.3 *Source:* Country Reports

**Americas** In North America, seed production and distribution systems are well-developed and dominated by the private sector. Reports from Latin American vary, but it appears that seed production and distribution are both primarily controlled by the private sector.

### An assessment of the seed sector

In many countries, the formal seed sector has been able to meet the seed requirements of small-scale farmers only to a limited extent.[114] This is not due to lack of funding. In the late 1960s, the seed sector became the target of widespread official support hom both western donors and developing country governments with attention focused on formally organized public-sector national seed programmes. The FAO Seed Improvement and Development Programme, for example, has spent ò300 million on 500 projects in 120 countries,[115]while the World Bank funds 13 national seed projects, and 100 other projects with seed distribution components.

Recently, however, as a result of poor performances by public-sector seed companies and because of the demands of structural adjustment programmes, governments have cut subsidies to the seed sector, thereby reducing activities. More generally, government research and extension services have been reorganized[116] to reduce the responsibilities of government agricultural inputs and marketing agencies, and to place a greater emphasis on private and community-level activities.[117]However, private seed companies cannot meet all the needs of small-scale farmers either.[118] These farmers typically desire multiple varieties of seed for all crops, and in small amounts, at the right time and at a reasonable cost.[119] Usually, private seed companies do not find the production and distribution of seeds for subsistence crops or for farmers living in economically marginal and environmentally diverse areas economically viable.[120]

In an attempt to fill the gap between formal public and private seed sector activities, and in response to farmers' demands, some NGOs have engaged in projects to enhance the ability of communities to produce and distribute seed as a complement to the formal seed system.[121]

The effectiveness of NGO activities, however, could be further strengthened by improving their technical seed production skills.[122]

Worldwide, poor seed production and distribution systems are reported to be a constraint in the dissemination of improved crop varieties by 27% of countries providing information (Figure 4.4). In Africa, however, the figure is 84%.

A number of recommendations were made during the course of the preparatory process for the International Technical Conference to strengthen seed distribution systems, with an emphasis on the need to promote on-farm farmer-level seed production, and to support informal seed exchange mechanisms.[123]

**Poor seed distribution systems as a constraint to the distribution of improved varieties** (% of countries reporting)

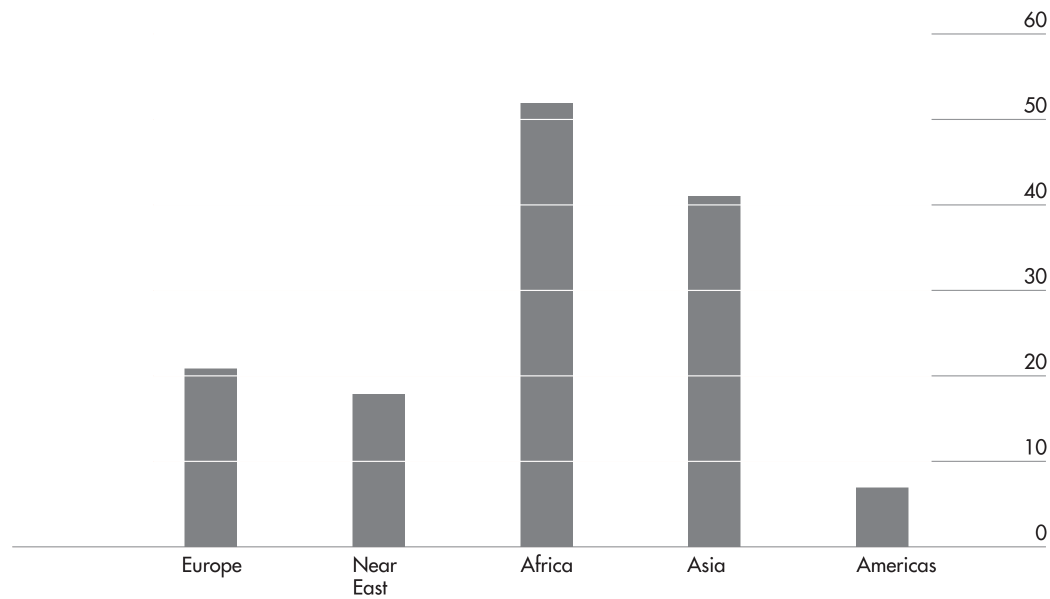



Figure 4.4 *Source:* Country Reports

Further, there is a need to determine appropriate roles for the public sector, private industry and for the informal sector, and a need to promote complementarity between them. The countries of Central America and Mexico recommended the strengthening of seed systems for both certified and non-certified seeds.[124] In some situations, small-scale farmers' own community-based seed dissemination mechanisms can provide farmers with access to seed of both traditional and modern varieties. Moreover, the quality of seed reaching farmers in this way can be comparable to that of formal-sector seed companies.[125]

Community-based seed diffusion mechanisms have, however, the capacity to handle only small quantities of seed within a limited geographical area. Their activities would therefore need to be strengthened. There is also a need to put in place adequate capacity to multiply and distribute landraces to farmers.[126]

Most countries have established seed regulations, with the following three basic objectives: (i) to protect the country's agriculture from imported pests, diseases and weeds; (ii) to protect farmers from poor quality seed (iii) to ensure plant breeders are compensated for their efforts.[127] Seed certification is concerned with ensuring that the seed for sale is actually of the variety named, and that the seed is of optimum and stated quality. There is a need to ensure that such regulations are supportive of seed production and distribution activities (see Chapter Five).

### 4.3.5 Marketing and processing

The potential for developing export markets for many indigenous under-utilized crops and plant species is increasing. Landraces contain important traits for crop improvement and they can play a major role in sustainable agricultural systems, particularly in marginal environments. Representatives of countries at the Mediterranean sub-regional meeting proposed that the distribution and commercialization of landraces should be promoted. The suitability of landraces for low-input cultivation systems make them good candidates for natural or organic agriculture.

There is a need to evaluate the special characteristics of certain landraces — flavour, shape, colour, — with a view to their exploitation in niche markets.[128] There is also a need to review seed regulatory frameworks for their effect on the conservation and use of PGRFA. Further, flexibility of implementation or, if need be, the creation of special categories to allow for the distribution and commercialization of landraces, should be promoted.[129]

Germany has proposed that special brands and marketing channels be developed for products that have been produced with special regard for sustainable conservation and use of plant genetic resources (e.g., old crops and varieties), and that registration requirements be reviewed wherever they undermine the sale of old varieties or landraces.[130]

Producers of traditional crop varieties and under-utilized crop species in developing countries, however, often do not have access to post-harvest processing technologies or adequate knowledge of potential market demands. Post-harvest processing may be necessary to develop marketable value-added products from many of the under-utilized or traditional crops.[131]

To overcome non-tariff barriers to some export markets, post-harvest processing to specific quality standards may be necessary. However, in some cases processing crops may actually lead to higher tariffs for exported goods.[132]

Links between small-scale producers and potential markets are also lacking, whether they be direct or through intermediaries with agricultural marketing expertise. Many developing countries lack capacity in export promotion services, which could help with the development of export markets.

Apart from governmental agencies, there are now several hundred alternative trading organizations, mainly in developed countries, whose mission it is to see that a fair proportion of sale profits on goods are returned to the small-scale producers in developing countries.[133] Examples include Oxfam Trading (the United Kingdom), Equal Exchange (the United States), International Federation for Alternative Trade (the Netherlands), CAA Trading (Australia), GEPA: Aktion Dritte Welt Handel (Germany) and Refugees International Japan (Japan).

These kinds of initiatives have the potential to contribute to the sustainable conservation and utilization of traditional varieties and under-utilized crop species. For instance, the International Development Research Centre (IDRC) in Canada has recently developed a project called "Food Links" which is exploring strategies to link small farmers and food producer groups in developing countries with commercial food enterprises and distribution channels in North America.[134]

## 4.4 DEPLOYMENT OF GENETIC DIVERSITY IN AGRICULTURAL PRODUCTION SYSTEMS

### 4.4.1 Introduction

So far, this Chapter has been concerned with the utilization of genetic diversity in crop improvement programmes. One aim for PGRFA utilization in plant breeding is to provide the genetic variability needed for selection. However, the extent to which genetic diversity is present in agricultural production systems (i.e. in the products of the plant breeding process) is also extremely important, if sometimes insufficiently emphasized. To assess this the entire crop production strategy should be reviewed.

Serious concern has been expressed regarding genetic vulnerability, and its effects on world food security.[135] Genetic vulnerability is defined 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"* (See Chapter One).[136] Genetic vulnerability may also be described as the poor deployment of genetic diversity in agricultural production systems.

The deployment of genetic diversity depends upon (i) the number and relative geographical distribution of the crop species and varieties grown, and (ii) the extent of diversity within and between such species and varieties. It is also affected by the methods used to deploy that diversity (e.g. the use of horizontal and vertical resistance against pests and diseases).

A number of factors linked to market requirements, the regulatory frameworks for variety release and seed distribution, and the nature of plant breeding itself, tend to promote genetic uniformity, rather than genetic diversity in farming systems. The question of deployment of genetic diversity is rarely addressed in any deliberate way through policy, either at the national or international level.

At the farmer level, however, many resource-poor families in developing countries apply mixed farming practices, and plant a diverse range of crops (e.g. maize, cassava, yams, taro, beans, millet, rice, potatoes, and sweet potatoes) to minimize the risk of total crop failure, particularly in marginal areas.[137] Many traditional agricultural systems also contain great intra-specific genetic diversity. For instance, over 90 different local bean types have been intercropped in Burundi, and over 2,000 local potato cultivars are grown in traditional Peruvian agriculture.[138] In the dry areas of West Asia and North Africa, heterogeneous barley landraces are grown to minimize the risk of crop failure.[139]

A viable strategy for the better deployment of diversity must address genetic vulnerability in farming systems (including both high-potential areas served by the formal sector as well as marginal areas where the informal sector tends to be relatively more important). To date, no such comprehensive strategy has been developed. However a number of distinct approaches, which have been addressed earlier in this Chapter, may have a role in the better deployment of diversity. These can be summarized as follows:

- the use of a wider range of species through, for example, the promotion of crop diversification using crop rotation, mixtures and agroforestry, and the development of under-utilized species (see Section 4.3.3.2);
- base-broadening approaches to pre-breeding or genetic enhancement (see Section 4.3.2) which provide more genetic diversity for the breeding cycle. Base-broadening permits, but does not ensure, higher levels of diversity;
- the specific adaptation approach to plant breeding (see Section 4.3.3.3) which tends to increase site-to-site diversity and, therefore, decrease genetic vulnerability at national, regional and global levels. However, it will not necessarily increase the number of varieties or the intra-varietal diversity on any particular farm;

- the farmer participatory approach to plant breeding (see Section 4.3.3.3) which, like the specific adaptation approach, will tend to increase site-to-site diversity. Again, while it will not necessarily increase the number of varieties or the intra-varietal diversity on any particular farm, experience suggests that it tends to do so.

Further approaches which may be appropriate in this context are:

- breeding of heterogeneous cultivars for outbreeding crops, for example, “composites” and “synthetics” (Annex 1-3);
- the use of alternative methods of gene deployment, such as gene rotation (especially of resistance genes), to ensure that different genes are used in different areas;[140]
- the use of appropriate regulations to maximize genetic diversity both within and between registered varieties;
- the release of a wider range of pre-bred germplasm of varieties at the pre-varietal stage;
- the provision of varieties or populations to farmers to enable them to incorporate new genetic materials into their landraces;
- the use of simple mixtures of cultivars and multilines;
- pyramiding of resistance genes, with on-going fresh infusions of diversity.

(These last two approaches are particularly relevant for reducing vulnerability to pests and diseases and are discussed under that heading below.)

Increased research is needed on the risk minimization potential of genetically heterogeneous crop production, both at the level of intra-species diversity (landraces, mixtures, multilines) and for inter-specific diversity (multi- and inter-cropping), especially for marginal environments.[141]

Commercial concerns as well as regulations on variety release, seed certification and plant breeders’ rights often discourage variability within cultivars. For instance, in commercial breeding, many naturally heterogeneous outbreeding crops are cultivated as homogeneous F1 hybrids. Though heterogeneous cultivars may be, on average, more stable performers,[142] inbred lines or hybrids are sought.

And even though it may be a positive agronomic characteristic, releasing heterogeneous cultivars in self-fertilizing cereals is not allowed in many countries.[143]

Cultivar mixtures can only be composed of certified cultivars, whereas multilines which tend to change in composition are not allowed for sale in the European Union (EU). At the same time, however, cultivar mixtures are currently receiving increasing research attention in the EU.[144]

### 4.4.2 Breeding for resistance to pests and diseases

The breeding of disease-resistant cultivars has generally been a successful but often frustrating task: successful in terms of the numbers of cultivars released, frustrating in terms of their durability. The bulk of this research is based on single *race-specific* genes, which generally provide protection against the races of the disease prevalent at a particular point in time. Due to their simple genetics, such genes are often relatively easy to handle in breeding programmes. It is also easy, however, for pathogens to evolve into new resistance-breaking races. Typically, a resistance gene in a widely grown cultivar will lose its effectiveness within five to ten years, producing a "boom and bust" cycle of plant breeding and new cultivar release. The mildew resistant barley cultivar 'Emir', for example, was released in Denmark in 1966. Its area expanded rapidly until 1970, when it succumbed to a new race of the pathogen causing the mildew.[145] There are, however, significant exceptions to this, particularly for some soil-borne fungal, nematode or viral diseases.[146]

The number of pest and disease species which have developed resistance to common pesticides has also increased rapidly in recent years. More than 900 species of crop pests have evolved resistance to a wide range of pesticides, up from 182 in 1965.[147] More than one-third of all agricultural production is still lost to pests, the same proportion as a century ago.[148]

For countries with effective and advanced breeding programmes, new disease-resistant varieties can be developed and released quickly enough to replace those which succumb to diseases. In many developing countries, however, plant breeding facilities may not have sufficient resources to respond rapidly to crop failures caused by genetic vulnerability. Many countries may also be unable to afford to import modern pesticides, either due to the low income levels of their farmers or because governments lack foreign exchange reserves. For instance, while large banana producing companies spend tens of millions of dollars annually (up to 30% of their gross income) on fungicides to control black Sigatoka disease,[149] the fungicide option is not open to many resource-poor farmers dependent on plantain as a staple food.[150]

Recent biotechnological advances have allowed the development of pathogen-resistant transgenic plants with genes that are either derived from pathogens[151] (e.g. viral coat protein,[152] viral replicate genes,[153] avirulence genes[154]) or from other sources (*Bacillus thuringiensis* (B.t.) delta endotoxin[155]). These, however, are as yet unproven under long-term agricultural conditions and may, as in the case of vertical resistance genes, become less effective over time.[156] Comprehensive gene deployment strategies against vulnerability to biotic, such as pests and diseases, and abiotic, such as salinity, acid soils and drought stresses in crops will continue to be needed.

### Improving gene deployment for resistance to pests and diseases

Disease development in a field where plants with different resistance genes are grown together will be delayed, as a pathogen will only be able to develop on those individuals which are susceptible. The remaining resistant plants act as a diluting agent and delay the onset of an epidemic.

This effect can be achieved through different methods including:

- the use of cultivar mixtures or multilines;
- the use of gene pyramiding;
- the use of different resistance genes in different cultivars, fields, geographical regions, or seasons.

The effects of mixtures and multilines on epidemic build-up can be striking.

- In Iowa, the United States, for example, crown rust epidemics have been delayed and damage avoided in multiline cultivars.[157]
- The incidence of mildew in barley in the former German Democratic Republic fell from 50% to 10% over a five-year period when cultivar mixtures were grown to combat the disease. By the end of the 1980s, virtually all spring barleys in the country were sown as mixtures in a deliberate policy to reduce the need for fungicides.[158]
- Barley mixtures grown in Denmark have given more stable yields over the years than pure-line cultivars.[159]

Such practices are well known in other parts of the world, as can be seen by farmers' use of landraces as well as deliberately composited mixtures. The efficiency of the mixture effect has been documented in a number of crops.[160]

There are also alternatives to reliance on the commonly used race-specific genes for resistance to pests and diseases. A substantial body of scientific evidence shows that effective, more durable and unspecified resistance exists in most crops. This is known as horizontal resistance. Unlike the race-specific vertical resistance, this does not give complete immunity. There is some disease, though often at economically insignificant levels. Moreover, because the pathogen population is not subjected to strong selection pressures, epidemics do not occur. Horizontal resistance is generally thought to be polygenic; the durable resistance against rice blast of the Japanese cultivar 'Morobekaran' was recently found to be due to at least 12 genes.[161]

Horizontal resistance plays a significant role in many cultivars, but it is often overlooked in favour of the more easily handled, but frequently ephemeral race-specific genes. This is partly the result of methodological problems. It has been shown, however, that the use of horizontal resistance in breeding programmes can be straightforward, provided specific-resistance genes are kept out of the gene pool.[162]

### 4.4.3 Breeding for other traits

In addition to breeding for resistance to pests and diseases, the exploitation of genetic diversity for other traits is important in optimizing production and stability, particularly for small farmers in marginal or variable environments. The wealth of genetic variation in adaptive responses to soil and climatic conditions conserved in the world's genebanks is little known and used even less than that related to pest and disease resistance, but it may yet prove to be the most important genetic resource of all.[163]

There are many biotic and abiotic stresses[164] which limit crop productivity worldwide, and many plant breeding programmes have goals to overcome these. Many such programmes focus on improving varieties for specific characteristics in order to increase both quality and quantity of production. The vast number of different specific agronomic traits and the breeding programmes associated with them, preclude any in-depth analysis here, however, some of the traits and qualities that different breeders are working to improve are outlined in the Box 4.5.

## 4.5 ASSESSMENT OF MAJOR NEEDS TO IMPROVE THE UTILIZATION OF PLANT GENETIC RESOURCES

As already noted in Chapter One, better use of plant genetic diversity will be a prerequisite to meeting the challenges of development, food security and poverty alleviation. In particular, greater use of plant genetic diversity will be required in order to produce varieties adapted to the extreme and highly variable environments of low-productivity areas. The need to achieve sustainable productivity increases (with reduction in the use of agrochemicals and more efficient use of water and nutrient resources) is likely to place even greater reliance on the utilization of diversity in high-productivity areas.

During the preparatory process for the International Technical Conference a series of strategic actions were suggested:[165]

- place greater emphasis on under-utilized species, especially those outside of current IARC mandates;
- facilitate, where appropriate, the direct use by farmers of landraces and other material conserved in genebanks;
- promote the use of landraces in breeding programmes;
- strengthen capacities and improve training in plant breeding at the regional, national and local levels;
- increase collaboration between breeders and genebank managers;
- carry out evaluation of conserved germplasm, where necessary under conditions representative of the proposed area of use;
- increase pre-breeding activities, with adequate attention in particular to base-broadening programmes which require long-term support;
- research and development of methodologies for decentralized and participatory approaches to plant breeding;
- explore marketing opportunities for products of landraces and under-utilized species;
- review seed regulatory frameworks and other relevant policies and legislation in order to facilitate the greater use of genetic diversity.

In addition, more attention should be devoted to plant breeding approaches which will maintain and increase genetic diversity, and thereby reduce genetic vulnerability in the field. The need to maintain diversity in breeders' populations and in crop varieties grown on-farm as well as in *in situ* and in *ex situ* collections has also been identified. Crop-specific networks may play an important role in monitoring levels of diversity in the world's major crops.

### Box 4.5 Some traits and qualities subject to improvement by breeders

**Abiotic stresses**

- Drought and heat tolerance[166]
- Heavy metal and acid soil tolerance[167]
- Enhanced phosphorous uptake[168]
- Salinity tolerance[169]
- Cold and frost tolerance[170]
- Flood tolerance[171]

**Biotic stresses**

- Pest resistance
- Fungal disease resistance
- Bacterial disease resistance
- Viral disease resistance[172]
- Soil nematode resistance[173]

**Nutritional and harvest qualities**

- Higher protein quantity and quality[174]
- Staple crops with high nutrient densities[175]
- Seed quality and retention
- Improved post harvest qualities[176]
- Increased yield (fruit/seed size)
- Improved cooking quality

**Other characteristics**

- Apomictic crops
- Domestication of wild plants[177]
- Biological nitrogen fixation

Both the public and the private sectors have a role to play in the conservation and utilization of plant genetic resources. The appropriate division of responsibilities and labour between the two is a matter of national policy and planning. Even in the context of a strong private sector, the public sector will continue to be vital for many crop improvement activities, particularly those of a long-term nature, including pre-breeding of most species as well as the development of minor and under-utilized species and plant improvement in marginal environments.

The Commission on Plant Genetic Resources has noted the need to link conservation activities to the sustainable utilization of plant genetic resources, including plant breeding. Moreover, the Commission has emphasized the importance of improving the utilization of plant genetic resources for sustainable agriculture in marginal areas.[178] The Commission considers that support to farmers and their communities for the sustainable use of PGRFA can be a step towards the realization of Farmers' Rights.[179] To help close the circle of conservation and utilization, action will be needed so that the many small-scale farmers in marginal environments may benefit more from PGRFA.

## Chapter 4 endnotes

1 The subregional meeting for East Africa and the Indian Ocean Islands agreed for example that "in addition to international mechanisms for sharing benefits, benefits can and should be realized within the subregions by the utilization of indigenous plant genetic resources, and other resources found in the region, including the rich diversity of landraces which are adapted to the subregions". Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13 (f).

2 FAO Conference Resolution 5/89.

3 FAO (1995) *Report of the Sixth Session of the Commission on Plant Genetic Resources, 19-30 June 1995*. Document CPGR-6/95/REP para 71. FAO, Rome.

4 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13.2.

5 Pioneer Hi-Bred (1983) *Conservation and utilization of exotic germplasm to improve varieties.* Plant Breeding Research Forum, Pioneer Hi-Bred International, Des Moines, Iowa, USA.

6 Subregional preparatory meeting: Mediterranean Report, para 37.

7 Country Report Germany.

8 Country Report Czech Republic.

9 Country Report Ethiopia.

10 Subregional Synthesis Report: Southern Africa, para 81.

11 Country Report Thailand.

12 Subregional preparatory meeting: Mediterranean Report, para 38.

13 Information from Country Reports.

14 Subregional preparatory meeting: Mediterranean Report, para 38.

15 Like characterization data, evaluation data can also facilitate management of genebanks and the establishment of core collections.

16 Numerous Country Reports (including those of about 40 countries that identified evaluation as a unique need) and all Subregional Synthesis Reports. The need for the Global Plan to address this issue was also supported by the recommendations of the subregional meetings.

17 The precision of replies ranged from the percentages of the collection that had been subject to some form of evaluation to extremely crude estimates of the extent of evaluation, such as "it varies", "some", "little" or the citing of particular crop species (e.g. rice, sugar).

18 System-wide Genetic Resources Programme (1996). Report of the Internally Commissioned External Review of the CGIAR Genebank Operations. IPGRI, Rome.

19 The enhanced germplasm was derived from useful accessions identified during the LAMP Programme; Salhuana W, Jones Q and Sevilla R (1991) The Latin American Maize Project: model for rescue and use of irreplaceable germplasm. *Diversity,* 7:40-42.

20 Subregional preparatory meeting: South America Report, programme 4.6, activity 4.6.2.

[21] Country Report Kenya.

[22] Country Report Japan.

[23] Subregional preparatory meeting: Mediterranean Report, para 34.

[24] Country Reports Romania, Russia.

[25] For example: Brazil, Kenya, Guinea, Sierra Leone, Chile, Venezuela, Indonesia, Malaysia, Germany, Yemen, Ireland and Eritrea.

[26] Subregional preparatory meeting: Mediterranean Report, para 35.

[27] Brown AHD (1989) The case for core collections. In: *The use of plant genetic resources*, p. 136-156. Cambridge University Press, Cambridge, UK.

[28] Hodgkin T, Brown AHD, van Hintum ThJL, and Morales EAV (1995) *Core collection of plant resources*, p. 3-20. John Wiley & Sons. Chichester, UK.

[29] Holden JHW (1984) The second ten years. In: *Crop genetic resources: conservation and evaluation*, p. 277-285. George Allen & Unwin, London.

[30] Hodgkin T, Brown AHD, van Hintum ThJL, and Morales EAV (1995) *Core collection of plant resources*, p. 269. John Wiley & Sons. Chichester, UK.

[31] Sometimes genebank managers have been reluctant to accept the idea of designating part of their holding as a "core collection" for fear that by according a special status to the "core" they would be seen as degrading the importance of the remainder of the collection and thus tempt funding agencies to give a lower priority to funding the maintenance of accessions that were not part of the core. Core collections are not intended to replace existing genebank collections, but to present as much genetic diversity as possible in a smaller subset of samples to the users.

[32] Subregional preparatory meeting: Europe Report, para 44(d); Subregional preparatory meeting: North America Report, para 16(g ); Subregional preparatory meeting: West and Central Africa Report, para 44; Country Reports Mauritius, India, Slovakia, Germany, the Netherlands, Russian Federation.

[33] Country Report Germany.

[34] Subregional preparatory meeting: Mediterranean Report, para 33.

[35] Note that this is a simplified diagram, besides their current breeding populations, breeders often hold working collections, which may include old, "obsolete" varieties, as well as exotic material.

[36] Ibid.

[37] Subregional preparatory meeting: Mediterranean Report, para 37.

[38] Wych RD and Rasmusson DC (1983) Genetic improvement of malting barley cultivars since 1920. *Crop Science*, 23:1037-1040.

[39] An ultimate version of this is genetic transformation; the introduction of a single gene by genetic engineering. Some plant breeders consider that this may be an increasingly popular means of accessing and using germplasm collections in the future. One of the advantages of genetic engineering over sexual hybridization is that no "unwanted" genes accompany the transferred gene.

[40] Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biological Review*, 68: 539-562.

[41] Goodman MM (1985) Exotic maize germplasm: status, prospects and remedies. *Iowa State Journal of Research*, 59:497-527.

[42] Mengesha MH and Prasada Rao KE (1982) Current situation and future of sorghum germplasm. In: *Sorghum in the Eighties. Proceedings of the International Symposium on Sorghum*, p. 323-335. ICRISAT, India, 1981.

[43] Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biological Review*, 68:539-562.

[44] *Inter alia*, Canada, China, Germany, Malaysia, the Netherlands, Nigeria, Portugal, Spain, Sweden, United Republic of Tanzania. Subregional preparatory meeting: South America Report, recommendations i, iv(d), iv(e).

[45] Subregional preparatory meeting: Mediterranean Report, para 30.3.

[46] Anderson JR, Pardey PG and Roseboom J (1993) Sustaining growth in agriculture: a quantitative review of agricultural research investments. *Agricultural Economics,* 10:107-123; Eicher CK (1992) *Revitalizing the CGIAR system and NARs in the third world*. Staff Paper No. 92-73, Department of Agricultural Economics, Michigan State University, East Lansing, USA.

[47] Kannenberg LW and Falk DE (1995) Models for activation of plant genetic resources for crop breeding programs. *Canadian Journal of Plant Science*, 75:45-53; Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biological Review*, 68:539-562; Chang TT (1985) Germplasm enhancement and utilization. *Iowa State Journal of Research,* 59:399-424.

[48] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14, recommendation (xix); Subregional preparatory meeting: Southern Africa Report, para 12(xix); Subregional preparatory meeting: Mediterranean Report, paras 30, 37.

[49] Only 20 (13.5%) of the 148 countries submitting reports in time to be analysed reported the absence of a programme in plant genetic resources utilization; many of these countries (60%) being small island developing states. Information concerning those countries which have crop improvement programmes is, therefore, based on the reports of 128 countries.

[50] Although, as described below, Barbados for instance hosts the West Indies Sugar Cane Breeding Station which is a major producer of improved sugar cane varieties for the Caribbean Region.

[51] Brader L (1989) Agricultural development and plant biotechnologies. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by CTA and FAO, 26-30 June 1989, Luxembourg.

[52] Hamdan IY (1989) Current status of plant biotechnologies in the Near East and North Africa. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by CTA and FAO, 26-30 June 1989, Luxembourg.

[53] Massala R (1989) Plant biotechnologies in sub-Saharan Africa today. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by CTA and FAO, 26-30 June 1989, Luxembourg.

[54] Subregional Synthesis Report: East Africa, para 108.

55 Olembo NK (1991) Agricultural biotechnology. Kenya: A country study. Paper presented at the BIOTASK/ISNAR Seminar on Biotechnology Policy and the CGIAR, 1-5 September 1991. International Service for National Agricultural Research, The Hague.

56 Komen J and Persley G (1993) *Agricultural biotechnology in developing countries*: *a cross-country review*. ISNAR Research Report No 2. The Hague.

57 Singh RB (1989) Current status and future prospects of plant biotechnologies in developing countries in Asia. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by the Technical Centre for Agricultural and Rural Cooperation and FAO, 26-30 June, 1989, Luxembourg.

58 Chaverra H(1989) Current status of plant biotechnologies in Latin America and the Caribbean. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries.* Proceedings of an International Symposium organized by CTA and FAO, 26-30 June, 1989, Luxembourg.

59 Smith S and Salhuana W (1996). The role of industry in the conservation and utilization of plant genetic resources. Presentation to the ASSINSEL/GIBIP Workshop on the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture, February 15-16, 1996, Basel, Switzerland.

60 The rate of institutional change in the private sector is extremely rapid, with many mergers and acquisitions between companies, such as the recent Sandoz and Ciba-Geigy merger. No up-to-date comparative ranking of the world's largest plant breeding and seed companies was available at the time this book was drafted.

61 Information from Country Reports.

62 Anderson JR, Pardey PG and Roseboom J (1993) Sustaining growth in agriculture: a quantitative review of agricultural research investments. *Agricultural Economics*, 10:107-123.

63 Subregional Synthesis Report: Eastern Africa, para 122.

64 Subregional Synthesis Report: West Africa, para 107.

65 Subregional Synthesis Report: West Africa, para 97.

66 Information from Country Reports.

67 Country Report India.

68 Country Report the Philippines.

69 Country Report Bangladesh.

70 Subregional Synthesis Report: Pacific, para II A.

71 Full-time equivalent (FTE) scientists (i.e. with B.Sc. degree or above).

72 Bohn A and Byerlee D (1993) *Wheat breeding research in developing countries: investments and impacts*, part 1 of the 1993/94 World Wheat Facts and Trends. CIMMYT, Mexico.

73 Swaminathan MS (1992) *Contribution of biotechnology to sustainable development within the framework of the United Nations system. UNIDO* Research paper commissioned by the United Nations ACC Task Force on Science and Technology, 87 pp.

74 Vietmeyer ND (1986) Lesser-known plants with potential use in agriculture and forestry. *Science,* 232:1379; Hinchcliffe F and Melnyk M (1995) *The hidden harvest: the value of wild resources in agricultural systems*. International Institute for Environment and Development, London.

75 Country Reports Argentina, Germany, India, Ireland, the Niger, the Sudan, Nigeria and United Republic of Tanzania.

76 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xix); Subregional preparatory meeting: Southern Africa Report, para 12(xix).

77 Subregional preparatory meeting: Mediterranean Report, para 45; Subregional preparatory meeting: Central and West Asia Report, para 30; Subregional preparatory meeting: East Asia Report, para 24.

78 Subregional preparatory meeting: West and Central Africa Report, paras 46, 47.

79 Subregional preparatory meeting: West and Central Africa Report, para 47.

80 Subregional preparatory meeting: West and Central Africa Report, para 48.

81 *News and Views on Technology Transfer in International Development*, March 1996, Volume 6, No. 3.

82 Riley R (1989) Plant biotechnologies in developing countries: The plant breeders perspective. In: Sasson A and Costarini V (eds.) *Plant biotechnologies for developing countries*, Proceedings of an International Symposium organized by CTA and FAO, 26-30 June 1989, Luxembourg.

83 Hossain M (1994) Recent developments in Asian rice economy: challenges for rice research. In: *Workshop on Rice Research Prioritization in Asia*, 15-22 Feb 1994, IRRI, Los Baños, the Philippines.

84 Pinstrup-Andersen (1993) "Some limitations on production increases have become 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".

85 Chambers R and Jiggins J (1986) *Agricultural research for resource-poor farmers: a parsimonious paradigm*. IDS Discussion Paper No. 220, Institute of Development Studies, Brighton, UK.

86 Op. cit., endnote 3.

87 In reality, of course, there will be a gradation of productivity from high to low, with many intermediate levels. "High-potential" and "marginal" are referred to here for simplicity of presentation.

88 Subregional preparatory meeting: Mediterranean Report, para 3.

89 Subregional Synthesis Report: East Africa, paras 101 105.

90 Conway G, Lele U, Peacock J, Pineiro M, Ozgediz S, Griffon M, Hazell M, Caraslade H and Holmberg J (1994) A vision for the CGIAR: sustainable agriculture for a food secure world. In: CGIAR Secretariat (1995) *Renewal of the CGIAR: sustainable agriculture for food security in developing countries*. Background Documents on Major Issues, Ministerial-level Meeting, 9-10 February 1995, Lucerne, Switzerland.

91 Ibid.

92 The materials will usually also have been tested in specific disease nurseries etc. to avoid wasted selection efforts.

[93] See, e.g. CIMMYT´s "megaenvironment" concept in De Lacy IH, Fox PN, Corbett JD, Crossa J, Rajaram S, Fischer RA & van Ginkel M (1994) Long-term association of locations for testing spring wheat. *Euphytica*, 72:95-106. For a personal account of the wide adaptation concept in maize, see Troyer F (1995) Breeding widely adapted, popular corn hybrids. *Proceedings of the sixteenth EUCARPIA Congress, Jyvaskyla*, Finland.

[94] Op. cit., endnote 90.

[95] Country Report Ethiopia and Subregional Synthesis Report: East Africa, para 106.

[96] Information from Country Reports.

[97] ICRISAT (1990) *Annual Report 1990*, p. 77-78. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India. Pimbert MP (1991) *Participatory research with women farmers*. 30-mm video film. ICRISAT and the Television Trust for the Environment (TVE), Hyderabad and London.

[98] Country Report Ethiopia and Sub-regional Synthesis Report: East Africa, para 106.

[99] Sperling L and Berkowitz P (1994) *Partners in selection. Bean breeders and woman bean experts in Rwanda*. CGIAR Special Publication, 24 pp.

[100] Subregional preparatory meeting: West and Central Africa Report, para 45.

[101] Berg T, Bjørnstad A, Fowler C and Skroppa T (1991) *Technology options and the gene struggle*. NorAgric occasional paper, Norwegian Centre for International Agricultural Development, Agricultural University of Norway; Hardon J (1995) Participatory plant breeding. *IPGRI Issues in Genetic Resources*, No. 3, October 1995.

[102] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(b); Subregional preparatory meeting: Southern Africa Report, para 12 (xix); Subregional preparatory meeting: West and Central Africa Report, para 41; Subregional preparatory meeting: Mediterranean Report, para 44; Subregional preparatory meeting: Central and West Asia Report, para 27; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, Section 2.3 (D 1a).

[103] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14, recommendation (xix).

[104] Subregional preparatory meeting: West and Central Africa Report, para 41.

[105] Subregional preparatory meeting: Mediterranean Report, para 44;
Subregional preparatory meeting: Central and West Asia Report, para 27.

[106] Subregional preparatory meeting: West and Central Africa Report, para 41. See also op. cit., endnote 101.

[107] Sperling L, Loevinsohn ME, Ntabomvura B (1993). Rethinking the farmer's role in plant breeding: local bean experts and on-station selection in Rwanda. Experimental Agriculture 29:509-519. See also op. cit., endnote 59.

[108] Venkatesan V (1994) *Seed systems in sub-Saharan Africa*. World Bank Discussion Papers, Africa Technical Department Series No. 266; Rosell CH (personal communication, January, 1996) Seed Production Section, AGPS, FAO, Rome; Almekinders CJM, Louwaars NP and de Bruijn (1994) Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica*, 78:207-211; Cromwell E, Wiggins S and Wentzel S (1993) *Sowing beyond the state: NGOs and seed supply in developing countries*. ODI, London, 142 pp.

[109] See V Venkatesan, op. cit., endnote 108.

[110] Country Report Spain.

[111] Country Report Zambia.

[112] Country Report United Republic of Tanzania.

[113] Country Reports the Philippines, Pakistan.

[114] Cromwell E (1990) *Seed diffusion mechanisms in small farm communities: lessons from Asia, Africa and Latin America*. ODI Agricultural Administration Unit, Network Paper No. 21, ODI, London.

[115] Rosell CH, personal communication, January, 1996, Seed Production Section, AGPS, FAO, Rome.

[116] Umali D and Schwartz L (1994) *Public and private agricultural extension: beyond traditional frontiers*. World Bank Discussion Paper No. 236. Washington, DC.

[117] World Bank (1981) *Accelerated development in sub-Saharan Africa. An agenda for action*. Washington, DC.

[118] Jaffee S and Srivastava J (1994) The roles of the private and public sectors in enhancing the performance of seed systems. *The World Bank Research Observer,* 9:97-117.

[119] Op. cit., endnote 114.

[120] Cromwell E (1992) *Privatization and the seed supply sector*. Study for the OECD, OECD, Paris.

[121] Subregional preparatory meeting: Southern Africa Report, para 13 (xx); see also V Venkatesan, op. cit., endnote 108.

[122] See E Cromwell, S Wiggins and S Wentzel, op. cit., endnote 108.

[123] Subregional preparatory meeting: Southern Africa Report, recommendation (xx); Subregional preparatory meeting: Mediterranean Report, para 30: Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xix); Subregional preparatory meeting: South America Report, programme 4.6, activity 4.6.1.; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 7.

[124] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 7.

[125] Op. cit., endnote 114.

[126] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14, recommendation (xix); Subregional preparatory meeting: Southern Africa Report, para 12, recommendation (xiv); Subregional preparatory meeting: West and Central Africa Report, para 45; Subregional preparatory meeting: Mediterranean Report, para 36; Country Reports Portugal, Germany, Ireland.

[127] Kelly AF (1989) *Seed planning and policy for agricultural production*. Belhaven Press, London.

[128] Subregional preparatory meeting: Mediterranean Report, para 36.

[129] Subregional preparatory meeting: Mediterranean Report, para 42.

[130] Country Report Germany.

[131] Subregional preparatory meeting: West and Central Africa Report, para 48.

[132] Madeley J (1992) *Trade and the poor: The Impact of International Trade on Developing Countries, p. 55-71.* Intermediate Technology Publications, London.

[133] Madeley J (1992) *Trade and the poor: the impact of international trade on developing countries*, p. 147-157. Intermediate Technology Publications, London.

[134] Mirza N (1996) personal communication, Food Links, IDRC, Ottawa, Canada.

[135] National Research Council (1993) *Managing global genetic resources: agricultural crop issues and policies.* National Academy Press, Washington, DC. Pinstrup-Anderson P (1993) *World food trends and future food security.* IFPRI, Washington DC.

[136] See National Research Council, ibid. National Academy of Sciences (1972) *Genetic vulnerability of major crops.* National Academy of Sciences, USA.

[137] Clawson DL (1985) Harvest security and intraspecific diversity in traditional tropical agriculture. *Economic Botany*, 39:56-67.

[138] Brush SB (1977) Farming the edge of the Andes. *Natural History*, 86:32-40.

[139] Weltzien E and Fischbeck G (1990) Performance and variability of local barley landraces in Near-Eastern environments. *Plant Breeding*, 104:58-67; Van Leur JAG, Ceccarelli S and Grando S (1989) Diversity for disease resistance in barley landraces from Syria and Jordan. *Plant Breeding*, 103:324-335.

[140] Khush GS (1991) In: Stalker HT and Murphy JP (eds.) *Plant Breeding in the 1990s.* CAB International, UK, 351 pp.

[141] Jiggins J (1990) *Crop variety mixtures in marginal environments.* International Institute for Environment and Development Gatekeeper Series No. SA19, IIED, London.

[142] Becker HC and Leon J (1989) The concept of stability in plant breeding. *Plant Breeding*, 101:1-23.

[143] Baenziger PS, Peterson CJ, Morris MR and Mattern PJ (1989) Quantifying gametoclonal variation in wheat doubled haploids. In: Maluszynski M (ed.) *Current options for cereal improvement*, p. 1-9. Kluwer Academic Publishers, Dordrecht, The Netherlands. The authors discuss the value of homozygosity in cultivars, saying that the reason for the success and adaptability in Nebraskan wheats may be because of their releases of heterogeneous F3-family cultivars.

[144] For instance through the EU COST Action 817 covering “Population structure of airborne pathogens as a means of improvng strategies for disease control”, which has a working group on variety and species mixtures.

[145] Jørgensen JH and Torp J (1978) The distribution of spring barley varieties with different powdery mildew resistances in Denmark from 1960 to 1976. Annual Report of the Veterinary and Agricultural University, p. 27-44. Copenhagen.

[146] Fraser RSS (1990) Genes for resistance to plant viruses. *Critical Reviews in Plant Sciences*, 3:275-294.

[147] Pimentel D (1995) *Pest management, food security and the environment.* Cornell University, Ithaca, New York. (unpublished)

[148] May RM (1993) Resisting resistance. *Nature,* 361:593-594.

[149] Stover RH and Simmonds NW (1987) *Bananas.* Wiley, New York.

[150] Strobel GA, Stierle AA, Upadhyay R, Hershenhorn J and Molina G (1993) The phytotoxins of *Mycosphaerella fijiensis*, the causative agent of black sigatoka disease, and their potential use in screening for disease resistance. In: *Proceedings of the INIBAP Workshop on Biotechnology Applications for Banana and Plantain Improvement*, January 27-31, San Jose, Costa Rica.

[151] Kavanagh TA and Spillane C (1995) Strategies for engineering virus resistance in transgenic plants. *Euphytica*, 85:149.

[152] Beachy RN, Loesch-Fries S and Tumer NE (1990) Coat protein-mediated resistance against infection. *Annual Review of Phytopathology*, 28:451-474.

[153] Baulcombe DC (1994) Novel strategies for engineering virus resistance in plants. *Current Opinion in Biotechnology,* 5:117-124.

[154] Hammond-Kosack KE, Harrison K and Jones JDG (1994) *Proceedings. National Academy of Sciences, USA*, 91:10445-10449.

[155] Delanany X, Lavallee BJ, Proksch RK, Fuchs RL, Sims SR, Greenplate JT, Marrone PG, Dodson RB, Augustine JJ, Layton JG and Fischoff DA (1989) Field performance of transgenic tomato plants expressing the *Bacillus thuringiensis* var. kurstaki insect control protein. *Biotechnology,* 7:1265-1269.

[156] Holmes B (1993) The perils of planting pesticides. *New Scientist*, 1888:34-37.

[157] Frey K (1982) Breeding multilines. In: Vasil, Scowcroft and Frey (eds.) *Plant improvement and somatic cell genetics*, p. 43-72. Academic Press, New York.

[158] Wolfe (1992) Barley diseases: maintaining the value of our varieties. *Barley Genetics,* VI, Vol. II, p. 1055-1067.

[159] Jørgensen-JH (1989) Resistant barley varieties, variety mixtures and/or fungicides? *Sixth Danish Crop Protection Conference 1989*, p. 159-171. (In Danish, English summary).

[160] Browning JA (1988) Current thinking on the use of diversity to buffer small grains against highly epidemic and variable foliar pathogens, problems and prospects. In: Simmonds NW and Rajaram S (eds.) *Breeding strategies for resistance to rusts of wheat*, p. 76-90. CIMMYT, Mexico City.

[161] Wang GL, Mackill DJ, Bonman JM, McCouch SR, Champoux MC and Nelson RJ (1994) RFLP mapping of genes conferring complete and partial resistance to blast in a durably resistant rice cultivar. *Genetics*, 136:1421-1434.

[162] Simmonds NW (1991) The genetics of horizontal resistance in plants. *Biological Review*, 66:189-241.

[163] Evans LT (1993) *Crop evolution, adaptation and yield*. Cambridge University Press, UK, 500 pp.

[164] Boyer JS (1982) Plant productivity and environment. *Science*, 28:443-448.

[165] Subregional preparatory meeting: Southern Africa Report, recommendation (xix); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xix).

[166] Edmeades GO, Bolanos J, Lafitte HR, Rajaram S, Pfeiffer W and Fischer RA (1989) Traditional approaches to breeding for drought resistance in cereals. In: Baker FW (ed.) *Drought resistance in cereals*, p. 27-52. ICSU and CAB, Paris and Wallingford, UK; Ludlow MM (1993) Physiological mechanisms of drought resistance. In: Mabry TJ, Nguyven HT, Dixon RA and Bonness MS (eds.) *Biotechnology for aridland plants*, p. 11-34. Austin, University of Texas, USA.

[167] Carver BF and Ownby J (1995) Acid soil tolerance in wheat. *Advances in Agronomy*, 54:117-173; Rao IM, Zeigler RS, Vera R and Sarkarung S (1993) Selection and breeding for acid soil tolerance in crops. *BioScience,* 43:454-463.

[168] Johansen C, Lee KK, Sharma KK, Subbarao GV and Kuenemann EA (1995) *Genetic manipulation of crop plants to enhance nutrient management in cropping systems - 1. Phosphorous*. Proceedings of an FAO-ICRISAT Expert Consultancy Workshop, 15-18 March 1994, ICRISAT Asia Centre, Patancheru, India.

[169] Kumar D (1995) Salt tolerance in oilseed brassica - present status and future prospects. *Plant Breeding Abstracts*, 65:1439-1447; Cheesman JM (1988) Mechanism of salinity tolerance in plants. *Plant Physiology,* 87:547-580.

[170] Chen THH (1994) Plant adaptation to low temperature stress. *Canadian Journal of Plant Pathology,* 16:231-236.

[171] Senft D (1995) New rice survives extended flooding. *Agricultural Research*, October 1995, USDA Agricultural Research Service.

[172] Fraser RSS (1990) Genes for resistance to plant viruses. *Critical Reviews in Plant Sciences*, 3:275-294.

[173] Atkinson HJ, Urwin PE, Hansen E and McPherson MJ (1995) Designs for engineered resistance to root-parasitic nematodes. *Trends in Biotechnology*, 13:369-374.

[174] Habben JE and Larkins BA (1995) Genetic modification of seed proteins. *Current Opinion in Biotechnology*, 6:171-174.

[175] Graham RD and Welch RM (1994) *Breeding for staple-food crops with high micronutrient density: long-term sustainable agricultural solutions to hidden hunger in developing countries*. Paper presented to IFPRI Workshop on Food Policy and Agricultural Technology to Improve Diet Quality and Nutrition, 10-12 January 1994, Maryland, USA.

[176] Wenham JE (1995) *Post-harvest deterioration of cassava: A biotechnology perspective*. FAO Plant Production and Protection Paper 130, FAO, Rome, 85 pp.

[177] IAEA (1986) *Plant domestication by induced mutation*. Proceedings of an Advisory Group Meeting organized by the joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, 17-21 November 1986.

[178] Op. cit., endnote 3.

[179] FAO (1994) *Report of the First Extraordinary Session of the Commission on Plant Genetic Resources*, 7-11 November 1994, Document CPGR-Ex1/94/REP, para 19.

# CHAPTER 5
# The State of National Programmes, Training Needs and Legislation

## 5.1 INTRODUCTION

The successful conservation and sustainable utilization of PGRFA involves action by a wide range of people in every country — policy makers, planners, scientists, germplasm curators, breeders, rural communities, and farmers. Strong co-ordination mechanisms are required at the national level to enable all these actors to participate constructively.

The importance of national activities is emphasized in the Convention on Biological Diversity. Article 6 states that "each Contracting Party shall, in accordance with its particular conditions and capabilities:

a) develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes which shall reflect, *inter alia*, the measures set out in this Convention relevant to the Contracting Party concerned; and
b) integrate, as far as possible, and as appropriate, the conservation and sustainable use of biological diversity into relevant sectorial or cross-sectorial plans, programmes and policies."

The importance of activities at the national level was also recognized in the country-driven preparatory process for the International Technical Conference on Plant Genetic Resources. All sub-regional and regional preparatory meetings recommended the strengthening of national programmes, which is also mentioned in nearly all the Country Reports. In some countries, the preparatory process itself has contributed to the development of national programmes, or prompted recognition that a well-coordinated programme is needed.[1]

This Chapter describes the purpose and function of national programmes, based on the recommendations of the sub-regional meetings and drawing upon information in the Country Reports and Sub-regional Synthesis Reports. Section 5.2 contains a description of the main types of national programmes. Their status is reviewed, focusing on formal programmes and co-ordination mechanisms, activities and funding, and on the roles played by the public and private sectors, universities and non-governmental organizations (NGOs). The remainder of the Chapter examines training needs, national policies and legislation.[2]

## 5.2 NATIONAL PROGRAMMES

### 5.2.1 Purpose and basic functions of national programmes

The ultimate purpose of national programmes for the conservation and sustainable utilization of PGRFA, identified during the preparatory process for the International Technical Conference, is to contribute to national development and sustainable agriculture.[3] Within this context, national programmes should aim to identify and address national requirements for PGRFA.[4] To achieve these aims, national programmes need the capacity to carry out three basic functions:

- elaboration of policies and strategies to meet country objectives for PGRFA conservation and utilization;[5]
- co-ordination of activities within the country, facilitating participation and cooperation between all stakeholders;[6]
- provision of a focal point to foster regional and international collaboration.[7]

Box 5.1, on the next page, summarizes the purpose, functions and typical activities of national programmes.

Throughout the preparatory process, the need for co-ordination mechanisms through national committees or other bodies was emphasized.[8] There is a particular need to promote the links between the various actors involved in the conservation and use of genetic resources, including farmers' organizations, governmental institutions, research and teaching institutions, NGOs, women's groups and the private sector, all of which have complementary roles to play. In order to avoid creating additional levels of policy making, PGRFA concerns need to be integrated into existing planning and co-ordination mechanisms, within the established frameworks of national agricultural and forestry research systems.[9]

## Box 5.1 National PGRFA programmes

### Purpose

- to contribute to national development, food security, sustainable agriculture and the maintenance of biodiversity through the conservation and utilization of PGRFA

### Functions

- develop national polices and strategies
- co-ordinate national activities, involve all stakeholders and promote linkages
- provide basic building blocks for regional and international collaboration

### Activities

- inventorying, exploration, collecting
- conservation *in situ* and *ex situ*
- characterization and evaluation
- genetic enhancement
- crop improvement
- seed/variety production and distribution
- documentation and dissemination of information
- training and capacity building
- research
- fund raising
- development of legislation
- regulation of access and exchange of genetic resources
- public awareness

### Partners

- ministries and government departments (i.e. agriculture, forestry, natural resources, environment, science and technology, planning, research and education)
- universities, research and other educational institutions
- NGOs, farmers' organizations, women's groups
- private-sector and parastatal companies
- regional and international organizations and networks

*Source*: Recommendations of Sub-regional Meetings

The preparatory process emphasized the importance of providing adequate levels of funding if national programmes are to be sustainable. In addition, it was stressed that the national committees and other structures should not be too large, in order to promote efficiency and to avoid placing undue burdens on national resources.[10] Finally, the need for a strong legal basis was highlighted, in order that national programmes be supported politically and institutionally at the highest level.[11]

### 5.2.2 Types of national programmes

National programmes are meant to co-ordinate the efforts of the various national institutions and organizations concerned with PGRFA, thereby avoiding duplication of effort and exploiting the different strengths of each organization to the fullest.

There is no single recommended structure or blueprint for achieving the above,[12] however, an analysis of Country Reports shows that, in general, national programmes tend to fall into one of the following categories:

- **Formal centralized programmes** A central institution, for example, a national plant genetic resources centre, co-ordinates and carries out many national PGRFA activities. Thirty-five countries (24% of those submitting reports) state that they have such programmes.[13] Ethiopia is an example of a country with a centralized national programme. All its plant genetic resources activ-ities are administered by its Biodiversity Institute[14] which has been built up technically and in terms of its infrastructure to undertake *in situ* and *ex situ* conservation responsibilities.[15] A similar arrangement exists in India, where the National Bureau of Plant Genetic Resources (NBPGR) is responsible for India's comprehensive national plant genetic resources system in close collaboration with over 30 institutions and centres.[16]

- **Formal sectorial programmes** These involve the development of one or several national focal points with mandates in different fields of conservation. This model is based on the principle that activities are best carried out by individual institutions according to their different strengths - *in situ* conservation, *ex situ* conservation or plant breeding - while policy and planning decisions are governed by a co-ordinating committee comprised of relevant ministries, universities, NGOs and governmental departments.[17] Nineteen countries report having such programmes (13% of those providing reports), including Turkey, Germany, Kenya, Brazil and Japan.

- **Co-ordination only programme** Several countries, although they do not have formally established national programmes, do have co-ordination mechanisms as well as significant PGRFA conservation and utilization activities. Where co-ordination mechanisms function well, this approach can be as effective as an established national programme. The main disadvantages are the lack of formal recognition by the respective governments and the lack of a secure budget. Twenty countries (14% of those providing reports) fall into this category, including Morocco, Indonesia, Malaysia and Costa Rica.

In addition, ten countries (7% of those providing reports) indicate that they have national programmes under development.

Figure 5.1 shows the types of national programme strategies in different parts of the world. In total, approximately half of the countries providing Country Reports appear to have national programmes of one type or another.[18] National plant genetic resources committees exist in 59 countries, 40% of those submitting reports. Some of these committees have been set up as a first step in developing a national programme on plant genetic resources.[19]

**Status of national programmes**

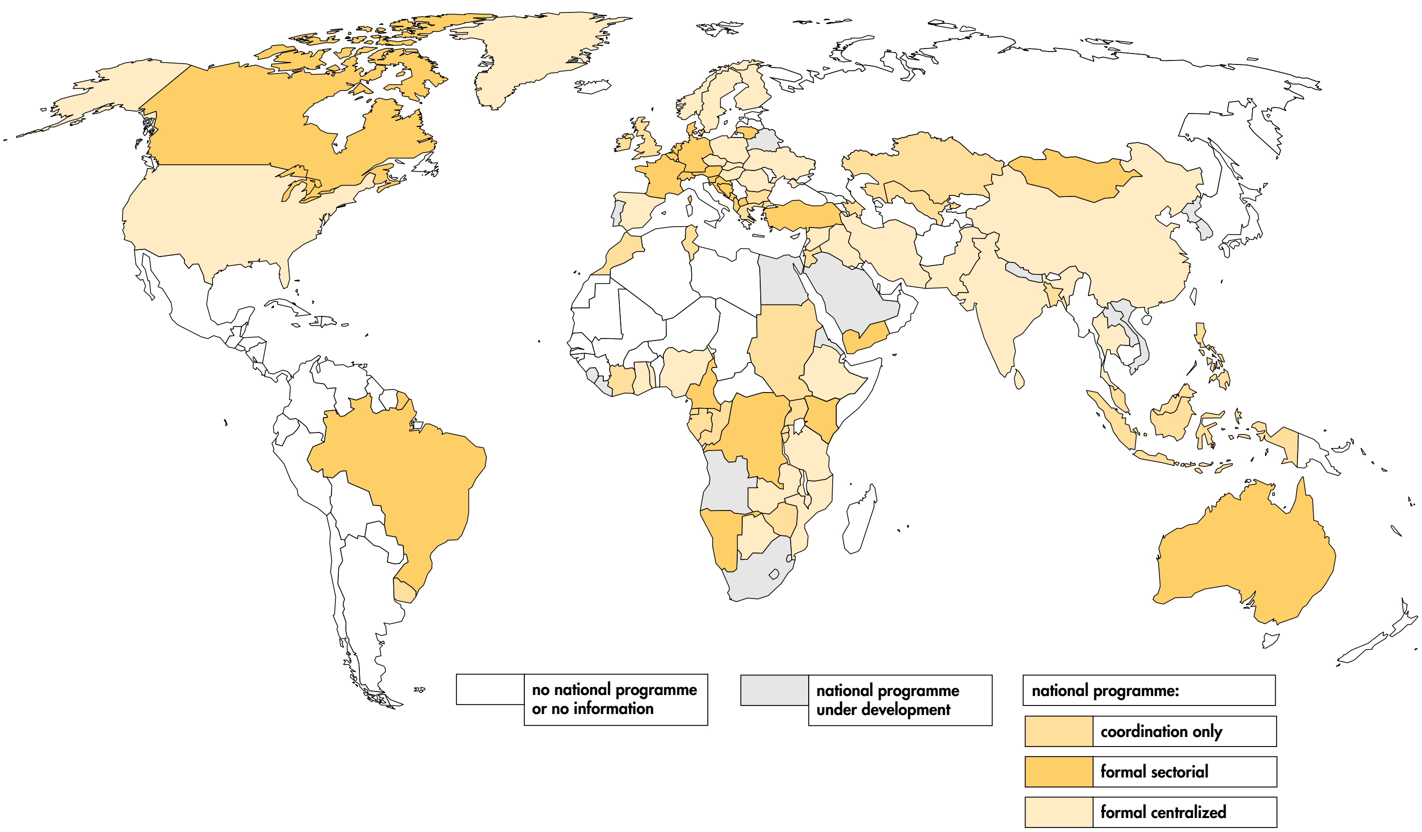



Figure 5.1 *Source:* Country Reports

National plant genetic resources programmes are often not comprehensive in scope or structure. Frequently, genebanks or the specialized institutions dealing with conservation of crop genetic resources are the focal point of a national programme, although they typically lack satisfactory linkages to other sectors and actors. It must therefore be emphasized that a clear distinction should be made between national programmes and national genebanks. Although the consolidation of national PGRFA germplasm collections is seen as an important component of national programmes, the establishment of co-ordinating mechanisms is considered an important prerequisite to implementing comprehensive national programmes.[20]

In contrast to the earlier, relatively narrow focus on conservation of plant germplasm for plant breeding, national PGRFA programmes now need to broaden their scope in line with the directives set in Agenda 21 and the Convention on Biological Diversity. Programmes now need to encompass strategies to conserve plant genetic resources *in situ,* in natural environments and on-farm.[21]

In particular, the need to link *ex situ* and *in situ* conservation through evaluation, genetic enhancement, plant breeding and seed distribution is vital. *Ex situ* conservation is traditionally carried out by plant genetic resources programmes within ministries of agriculture, while *in situ* conservation is usually carried out by government departments concerned with forestry, natural resources and possibly tourism, as well as by NGOs, farmers' groups and local community organizations.

Only 27 of the countries which submitted Country Reports indicated that *in situ* conservation was included in their national programmes. Similarly, only 26 countries indicated that utilization was included. Countries whose programmes cover both *in situ* conservation and utilization include Brazil, Cuba, Ethiopia and India. The absence of linkages between conservation and utilization is common throughout the world and this can be seen particularly in Eastern Europe and southern Africa, where a number of countries have well developed *ex situ* conservation facilities, but the links to utilization programmes are poor.

There is a need to place PGRFA programmes firmly within the context of national development plans as well as national environmental plans, national forestry plans and national biodiversity strategies. The commitment represented by Agenda 21 and the Convention on Biological Diversity has, in many cases, led to many more government bodies becoming involved with both policy and the practical aspects of plant genetic resources. It is even more important, therefore, that national co-ordination mechanisms be strengthened to link different government bodies.

### 5.2.3 State of development of national programmes[22]

**Europe** Most European countries have some sort of mechanism in place to co-ordinate the activities of the different actors, and many have advisory bodies to guide plant genetic resources programmes and policies. Co-ordination is essential for the cost-effective use of resources and funds, particularly in those countries with decentralized systems of conservation and utilization.[23]

The Nordic countries have a centralized regional programme called the Nordic Gene Bank (NGB). Sweden, however, is developing a national programme to cover species not included in the NGB's mandate. Truly national and centralized programmes are rare in Western Europe. Although national genebanks exist in Portugal, Greece, Ireland, The Netherlands and Spain, only the latter two are responsible for co-ordinating a national plant genetic resources programme.

Austria, France, Germany, Italy, Switzerland and the United Kingdom have more decentralized systems of *ex situ* conservation, involving several genebanks which hold particular categories of germplasm. These are organized into formal national programmes in Austria, France, Germany and Switzerland.[24] European Union (EU) countries have mandated the European Commission to co-ordinate genetic resources activities among countries within the EU.[25]

Most Eastern European programmes are centred around a lead institution which has responsibility for *ex situ* crop genetic resources conservation. In the Czech Republic, Hungary, Poland, Romania and Slovakia, these institutions are funded and administered by the government. Croatia and the Federal Republic of Yugoslavia (Serbia and Montenegro) have launched new national initiatives to establish plant genetic resources programmes.[26] With the break-up of the Soviet Union within which the N.I. Vavilov Institute coordinated an all-Union programme, the newly independent states are having to develop new national programmes. All three Baltic states have launched national projects on crop genetic resources within the framework of a regional collaborative project with the Nordic countries. In the Russian Federation, the VIR collection has been accorded the status of national collection.

In all these countries, however, implementation of national programmes for plant genetic resources is hindered by the lack of funds and many are now seeking international assistance.[27] National committees for plant genetic resources have been established in five Eastern European countries.

**Near East** In the region as a whole, the West Asia and North Africa Plant Genetic Resources Network (WANANET) has played an important role in strengthening national programmes by reinforcing the role of the national plant genetic resources committees and encouraging co-ordination between different institutions within each country and between programmes throughout the region. Through WANANET, successful national plant genetic resources committees have been established or strengthened in the Islamic Republic of Iran, Jordan, Pakistan and Turkey.[28] In Iraq, Saudi Arabia and Yemen, national programmes are at an advanced formative stage.[29] A national steering committee on plant genetic resources is being formed under the auspices of the Palestinian National Authority.[30]

In addition, Israel has a well organized national programme and participates actively in the European Cooperative Programme on Crop Genetic Resources Networks (ECP/GR). The Central Asian republics of the former Soviet Union do not have national programmes and they have yet to define the organizational, institutional and legal structures required.[31]

Efforts to develop national programmes are under way in most countries of the South and East Mediterranean. Morocco, in particular, has a co-ordination mechanism which works well.[32] In many other countries, however, the lack of co-ordination between different institutions dealing with plant genetic resources activities is a major bottleneck to programme development. Although, there are many well developed plant genetic resources activities conducted by various institutions, in Egypt, for example, lack of co-ordination has led to a dispersal of resources.[33]

**Africa** The development of national programmes is most advanced in Southern Africa[34] where the Southern Africa Development Community Plant Genetic Resources Centre (SPGRC) has provided an impetus for the initiation and development of national programmes. Most countries in the region have established national plant genetic resources centres (NPGRCs) as counterparts to this regional project. In South Africa, however, the view is that national plant genetic resources activities should be decentralized to institutions concerned with specific activities, such as agriculture, forestry and wildlife.[35] Most of the countries in Southern Africa also have plant genetic resources committees which include representatives from governmental departments, universities and research institutions. In some countries, such as Lesotho and Zimbabwe, NGOs are also members of the committee.[36]

In East Africa, national programmes are at various stages of development. These include well-developed structures in Ethiopia and Kenya, those at an advanced formative stage in the Sudan and Uganda, and those still in an initial phase of programme development in Burundi, Eritrea and Rwanda.[37] While Ethiopia has a centralized programme, the national programmes in Kenya, Uganda and the Sudan are sectorial.[38] Ethiopia, Kenya and, to a large extent, the Sudan and Uganda, have effective decision-making mechanisms for the conservation and use of genetic resources, though, except for Ethiopia, these lack a legal infrastructure.[39]

The Indian Ocean island states do not have national programmes per se, but there are policies and programmes within the various departments and institutions which, at least in part, address the conservation of plant genetic resources. In most countries, there are national research institutions, universities and NGOs which carry out activities related to plant genetic resources.[40] However, co-ordination is generally lacking among them. One means of catalyzing cooperation and interaction is to organize national plant genetic resources workshops. To date, however, only two countries in the sub-region, Mauritius and Madagascar, have held national workshops, each sponsored by IPGRI.[41]

Few formal national programmes exist in Central and West Africa. Nigeria and Ghana have national centres for plant genetic resources, but, in general, plant genetic resources activities are carried out in a sectorial manner by the various institutions concerned. Co-ordination is non-existent in more than half of the countries, and efforts to establish national committees are hampered by the lack of official recognition and funding.[42]

**Asia and the Pacific** Considerable attention is being paid to plant genetic resources by the governments of East Asian countries, and a significant amount of funding has been allocated to national programmes. The strongest national programmes have been established in Japan, the Republic of Korea and China. The Democratic People's Republic of Korea and Mongolia, on the other hand have relatively weak national programmes.[43] Japan, Mongolia and the Republic of Korea have set up advisory bodies which are responsible for developing proposals, long-term planning and making recommendations for the allocation of financial and other resources.[44]

Among the countries of South Asia, the need to develop national co-ordination is particularly noted by Bangladesh, Nepal and Sri Lanka.[45] Although all three countries have identified the need for a national programme, they are not, presently, able to establish strong programmes without international help.[46] India, on the other hand, with a high degree of awareness among its decision-makers of the importance of conservation and utilization of PGRFA, has developed a model national programme. The NBPGR is responsible for planning, organizing, conducting, promoting and co-ordinating all activities related to plant exploration, collection, introduction, conservation, exchange, evaluation and documentation, as well as quarantine. Its mandate covers all activities, including the development of training capabilities to meet in-country as well as regional needs.[47]

In many South East Asian countries, irrespective of whether a formal national programme exists, plant genetic resources activities are carried out by various institutions, most of which are concerned with crop improvement programmes. National plant genetic resources committees co-ordinate activities and, in some cases, also have an advisory function. These committees play an important role in PGRFA programmes in Indonesia, Malaysia, the Philippines, and Thailand. NGOs are represented on national committees in the Philippines and Indonesia.[48] Integrated national programmes exist in Thailand and Viet Nam, while there is a well-coordinated plant genetic resources network in the Philippines. Indonesia and Malaysia have co-ordination mechanisms but no formal national programme. National programmes are non-existent in Bhutan, Cambodia and Myanmar. There are also no national programmes in the Pacific Island countries.

Australia and New Zealand have an organized and coordinated programme for managing plant genetic resources for food and agriculture which covers the major crop and pasture species. The mechanism for coordinating the activity is through the Australian and New Zealand Network of Plant Genetic Resource Centres (ANZNPGRC) which consists of nine centres managed by agencies of the New Zealand Government, Australian Commonwealth Government or Australian state or territory governments.

The Commonwealth Government of Australia maintains a Plant Introduction Unit which maintains a register of plant introductions to Australia and stores back-up samples from many of the centres.[49]

**Americas** Among the countries of Latin America and the Caribbean, formal national programmes exist only in Brazil, Cuba and Honduras, but the need to develop such programmes is strongly felt throughout Central and South America. National plant genetic resources committees exist in six countries. Plant genetic resources activities are carried out by various institutes with crop-specific mandates in most countries in the region. In Argentina, Chile, Ecuador, Peru and Venezuela there are lead institutions which have responsibility for plant genetic resources activities. Other institutions are also involved, though co-ordinating mechanisms are not always in place.

In the Caribbean sub-region, only Cuba is reported to have a functioning integrated national plant genetic resources system supported by legal instruments. Its national system involves 18 research institutions, two botanical gardens, five ministries, one service agency and one NGO. In the other Caribbean countries, individual institutions have conducted ad hoc plant genetic resources activities without, however, establishing a formal national system or formulating and enacting official policies and legislation. In North America, both Canada and the United States have well-developed national programmes.

### 5.2.4 Funding of national programmes

Most countries, while recognizing the need for international financial support, argue that the basic running costs for a national programme should be provided by governments to ensure the sustainability of national programmes.[50] Many countries, however, do not have specific budget allocations for plant genetic resources activities, and their national programmes are, as a result, weaker.[51] Only one-fifth of the countries reporting have specific budget lines for plant genetic resources activities.

Generally, in **Africa**, the level of political importance given to national programmes and plant genetic resource activities is reflected in the funding allocated to them. In Ethiopia, for example, the high level of political awareness and commitment to conservation of plant genetic resources is reflected in the budget allocation. Similarly, in Eritrea, political awareness and commitment to conserve plant genetic resources is quite high, and this has led to the incorporation of a component on plant genetic resources in their recently developed agricultural research master plan.[52]

In most African countries, however, lack of funding is a major problem. In Ghana, Nigeria, Zambia and Mozambique there is a separate budget for the PGRFA programme, but it is generally inadequate given the magnitude of the tasks to be undertaken. In most other countries, the national programmes and plant genetic resources activities are under funded and often largely dependent on external funding.

In the **Near East**, due to the lack of government policy covering plant genetic resources activities, most conservation programmes, with the exception of Israel, Turkey and to some extent the Islamic Republic of Iran, do not receive enough support from policy makers and their budgets are insecure. In Tunisia, for instance, genebank facilities were established in the early 1980s, but after a few years the project began to face difficulties due to lack of co-ordination and funds.[53] In the Central Asian republics of the former Soviet Union, a major constraint to the development of national programmes is the lack of funding resulting from their political transformation and abrupt change in the area's economic situation. Most national efforts are devoted to maintaining a satisfactory level of activities in sectors which give rapid economic returns, thereby neglecting areas which require long-term support, such as conservation, plant breeding and other scientific research.[54]

In **Asia and the Pacific**, funds are a constraint to national programme implementation in China, Mongolia and the Democratic People's Republic of Korea.

**Americas** Lack of funding is mentioned as a constraint by all the countries in Central America and Mexico, and by most of the countries in the Caribbean and South America. In Argentina, Columbia and Nicaragua, the lack of a national PGRFA programme, and the consequent lack of co-ordination is reported to exacerbate funding problems.

In **Europe**, most programmes appear to have adequate institutional structures and capacities, as well as enough government support to ensure relatively secure, long-term conservation of plant germplasm *ex situ* and to meet the needs for its use in plant improvement. Several countries, however, particularly in Eastern and Southern Europe, are experiencing funding difficulties. Lack of facilities, personnel and funds have seriously constrained the emerging national programmes of the newly independent states. Furthermore, political support for PGRFA activities comes mainly from the ministries or institutions directly involved, and not from higher levels. As a consequence, agricultural research and plant genetic resources programmes are affected by general funding cuts.

## 5.2.5 Role of the public, private and informal sectors

### Public and private sectors

Both the public and the private sectors have a role to play in the conservation and utilization of plant genetic resources. While the private sector may undertake profitable activities, such as plant breeding and seed production and the distribution of seed and planting material of some crops, public sector support is vital for many other activities. The latter include long-term activities such as the conservation and pre-breeding of most species, as well as the development of minor and under-utilized species, and plant improvement in marginal environments (see Chapter Four). Although the private sector may invest in breeding cash crops, it is unrealistic to expect it to invest in the conservation, genetic enhancement and breeding of under-utilized crops.[55]

Private companies are becoming increasingly involved in plant breeding and biotechnology, but their involvement is restricted to a limited number of major crops and there is a need for expansion of private-sector activities in many parts of the world. Privatization programmes and other initiatives to support the private sector need to be accompanied by investment in the public sector in those activities the private sector cannot address. Furthermore, collaboration between the public and private sectors should be promoted, and the private sector should be involved in the definition of priority activities.[56]

### Universities

Although universities do not usually have institutionalized mandates for the conservation of genetic resources per se, they are important players in PGRFA conservation and utilization. National co-ordinating committees are considered incomplete without representation from the agricultural departments of universities and colleges which play an important role in research and training. Universities are usually active in areas such as germplasm collecting, characterization, evaluation, utilization, diversity studies and biotechnology. The role of universities in training is covered in more detail in Section 5.3.

### NGOs and the informal sector

The informal sector is made up of local community groups, NGOs, farmers and other users of PGRFA. This sector is an important, though fragmented, contributor to conservation through on-farm use and maintenance of plant genetic resources.

Although NGOs and local communities are becoming more and more involved in *in situ* conservation around the world, with very few exceptions, they do not participate in the development of national programmes or policies. Linkages need to be developed within this sector, and between it and the formal sector.

Countries need to establish mechanisms for cooperation between the formal and informal sectors to exchange materials, information, expertise and other resources.

The formal sector can provide NGOs and the informal sector with technical information on conservation methods, and help with strategies for germplasm enhancement. The formal sector can also supply farmers with germplasm from genebanks for multiplication and rehabilitation within local agricultural systems. In turn, farmers' associations and NGOs can be useful partners to the formal sector in carrying out inventories, performing collecting missions, documenting traditional knowledge, growing out collections, operating community seed banks and assisting with research in complex and risk-prone environments. In addition, NGOs often play a useful role in providing environmental education, creating public awareness and establishing links with farming communities.[57]

In Europe, a wide range of NGOs are involved in PGRFA conservation and utilization, and related advocacy work.[58] In the United States, a number of NGOs, for example Seed Savers Exchange, are collaborating with the formal sector, resulting in mutually beneficial exchanges of seeds and information. The National Plant Germplasm System (NPGS) provides seed-storage facilities for NGOs, such as the Centre for Plant Conservation, and conducts research on the storage of seed of threatened or endangered species.[59] In Canada, NGOs, notably the Heritage Seed Programme, are involved in many activities which contribute to germplasm conservation. The Heritage Seed Programme specializes in varieties of vegetables and fruit which are not suitable for large-scale commercial production. NGOs are represented on Canada's National Plant Genetic Resources Committee.[60] Further examples of the role played by NGOs, particularly in relation to *in situ* conservation, are given in Chapter Two.

## 5.3 TRAINING

Together with the development of national programmes, the need for training was identified as a priority by virtually all countries reporting.[61] Most sub-regional meetings recommended that training activities be promoted through the Global Plan of Action. Constraints to training are summarized in Table 5.1.

In many countries, in the past, training in plant genetic resources was carried out in an infrastructural vacuum. There were few if any national plant genetic resources programmes or activities for which trainees could work and most found employment in other sectors, not necessarily related to plant genetic resources. This is still the case in some countries where there are no established PGRFA posts, and officers with training in plant genetic resources are forced take other positions.

**Table 5.1 Obstacles to training and how they might be overcome**

| Constraint | Need |
|---|---|
| • Lack of infrastructural framework | • Development of national programmes with permanent professional posts |
| • Lack of resources and funds | • Domestic and international financial support<br>• reduction costs through regional collaboration |
| • Lack of suitable facilities and institutions, including an inadequate number of training opportunities | • Development of regional centres<br>• national capacity-building in training |
| • Loss of trained staff, high staff turnover | • Incentives (salaries etc.) |
| • Lack of appropriate training materials and suitable curricula | • International collaboration for the development of training modules |

*Source*: Country Reports, Subregional Synthesis Reports and Subregional meetings

Another problem, common to many countries, is the high staff turnover caused by low salaries and the lack of incentives in government employment.[62]

Today, however, training is generally being carried out with national programme needs in mind, in particular, the need for qualified personnel to staff national PGRFA centres and genebanks.[63] Furthermore, despite the above-mentioned limitations and the need for financial assistance to strengthen training programmes, significant capacity for training does exist in many parts of the world. Since its inception, IPGRI/IBPGR has trained 1,850 persons, coming from virtually all developing countries.[64]

**Africa** In collaboration with IPGRI, the University of Zambia has developed a detailed curriculum for a MSc course in plant genetic resources, but the programme itself is not operational. In addition, this institution collaborates in short-term courses in plant genetic resources with the help of the University of Birmingham (United Kingdom), IPGRI and SPGRC. In Malawi, tertiary institutions, such as Bunda College of Agriculture (University of Malawi), the Natural Resources College and the Malawi College of Forestry could, with financial assistance, develop curricula in the field of conservation. In East Africa, the Crop Science Department of the University of Nairobi is developing a curriculum for undergraduate and postgraduate training in plant genetic resources conservation in collaboration with the University of Birmingham and IPGRI.[65]

**Asia and the Pacific** The need for training with a strong emphasis on management and policy issues is recognized in the region.[66] Several institutions have been identified as having the potential to provide training at the regional level in plant genetic resources activities, including the University of The Philippines at Los Baños, the National University of Malaysia, the Indian Agricultural Research Institute and NBPGR, Bogor Institute of Agriculture in Indonesia, and the University of the South Pacific in Western Samoa. Other relevant institutes include: the Australian Tropical Forages Genetic Resource Centre, the Australian *Medicago* Genetic Resource Centre and the Margot Forde Forage Germplasm Centre in New Zealand.[67]

**Americas** Training needs, and capacities to provide training, vary considerably in Latin America and the Caribbean. The need for courses and training in plant genetic resources at all levels is reported by Columbia, the Dominican Republic, Ecuador, Honduras, Nicaragua, El Salvador and most Caribbean countries. Guatemala and Venezuela are able to provide graduate level training, but report a need for training at the post-graduate level; Argentina, Chile and Peru are able to provide training up to the MSc level. Nevertheless, Argentina reports the lack of trained scientists as a main constraint in further developing plant genetic resources activities. Peru has a national training infrastructure at both the graduate and postgraduate levels. However, international cooperation is needed to enhance all these courses. In addition, Peru has an agriculture extension programme for farmers which is primarily focused on training for *in situ* conservation. Various training courses are also offered by CATIE in Costa Rica.

Chile and Cuba have organized international courses in plant genetic resources activities, and there is a proposal to organize a short course with a Caribbean emphasis every year in Cuba. This, however, will require financial and logistical support. Brazil has the capacity to provide training in plant genetic resources, mainly as a specialized option within graduate courses related to plant research. The Centro Nacional de Pesquisa de Recursos Genéticos e Biotecnologia (CENARGEN) offers short courses in germplasm management and conservation, plant protection, quantitative genetics and molecular characterization of germplasm. Such courses are in great demand in Latin American countries as well as the lusaphone countries of Africa.[68]

**Europe** Trained staff and training opportunities are, generally, available. In some countries, however, there are not enough established posts to cover plant genetic resources activities. Many countries in Western Europe are very strong in providing training courses, with some institutions, most notably the University of Birmingham in the Unitd Kingdom, specializing in training students from developing countries.[69] The Birmingham MSc programme, the only fully-functioning MSc programme devoted to plant genetic resources, can only accept a small portion of the hundreds of applicants it receives yearly. The Agricultural University of Norway offers an English-language MSc programme on management of natural resources including PGRFA but, like Birmingham, it cannot accommodate the large demand for PGRFA-focused training. Some countries in Eastern Europe - Albania, Croatia, Estonia, Lithuania, the Republic of Moldova and Ukraine - however, identify training as a major need.[70]

During the preparatory process, all regions identified a range of training needs, including:

- design of modules on plant genetic resources for inclusion in each country's university courses on agriculture, horticulture, forestry and botany;[71]
- advanced and specialized courses at regional level, particularly in: systematics and taxonomy; population genetics; ecology; ethnobotany; genetics and plant breeding; seed technology, production, evaluation and utilization; germplasm management; and policy issues;[72]
- regional- and national-level short courses in practical techniques for plant breeding, seed production and distribution, conservation technologies, quarantine and collecting, and documentation and information management;[73]
- training for managers of national programmes in policy development and analysis, the identification and solving of constraints, and the enhancement of interinstitutional and intercountry cooperation;[74]
- training for farmers and extension agents.[75]

In addition to the above, there is a need to emphasize on-site training, especially for women as they play a crucial role in managing traditional varieties and under-utilized species.[76] Training of trainers and on-site training of technicians are also important.[77] Other suggestions include the strengthening of environmental education in secondary schools[78] and the development of programmes to raise public awareness of the value of PGRFA.[79]

Finally, there is a need to strengthen training capabilities at all levels, both nationally and regionally, in order to reduce costs and allow an increase in the number of people receiving training (including by making training available in different languages), and to encourage trained staff to remain with the national research systems. There is also a need for periodic refresher training courses. National and regional institutions which have the capacity or potential to offer training in plant genetic resources, mentioned above under the various regions, were identified during the preparatory process for the International Technical Conference.

## 5.4 NATIONAL LEGISLATION

Existing policies and laws concerning PGRFA and related issues of environmental and natural resources management are beset with various technical, policy and socio-political constraints. One reason is that such laws have been developed piecemeal over a long period of time.[80]

At a practical level, putting the various laws and policies into practice has been impeded by inadequate implementation and enforcement mechanisms and a lack of logistical, financial and human resources. In addition, there is a lack of proper co-ordination and integration mechanisms.

While most countries have phytosanitary regulations, other laws concerning plant genetic resources are often poorly understood, inadequately developed and implemented, or simply non-existent. There is a need to assess and adapt existing legislation and, sometimes, to develop new laws in line with the real needs of the countries, taking into account international requirements, and fully respecting the interests of farmers and local communities.[81]

### 5.4.1 Access to genetic resources

There is a widely recognized need to put in place legislation regulating the movement of genetic resources, in line with the Convention on Biological Diversity and the needs of individual countries.[82] The Sub-regional Meeting for West and

Central Africa suggested that the International Code of Conduct for Plant Germplasm Collecting and Transfer, developed by the Commission on Plant Genetic Resources, could be used as a model for national legislation.[83]

Policies concerning access to plant genetic resources are currently in a state of flux. Some countries are beginning to put in place mechanisms to enforce “prior informed consent” and “access on mutually agreed terms”. Others are awaiting the outcome of current discussions of these issues by the FAO Commission on Genetic Resources for Food and Agriculture and the Conference of Parties to the Convention on Biological Diversity. In general, the legal status of existing *ex situ* collections is undefined and responsibility for the distribution of material lies, in practice, with the curator and only rarely with a higher authority.

The policy of the United States is to provide all bona fide users free access to public germplasm held in the NPGS genebanks. Requests are referred to owners when intellectual property laws such as patents, plant variety protection and trade secrets apply.[84] Similarly, all European countries state that the plant genetic resources in their existing collections are freely available to bona fide users. Many also state their adherence to the International Undertaking on Plant Genetic Resources. The privatization of agricultural research institutions in many Eastern European countries, however, has given rise to concern over ownership and the security of collections, as well as implications as to their accessibility to governments and scientists.[85]

The African Ministerial Conference on Environment (AMCEN) has adopted a common position *vis-à-vis* the Convention on Biological Diversity,[86] including a recommendation that African countries impose a temporary ban on access to biological resources pending the elaboration of definitive legislation on the subject.[87] The genetic resources programme in Angola requires all recipients of local germplasm to sign a statement that the material will be used only inside the country for development purposes, unless permission to export it is requested and granted. Angola is in the process of drawing up regulations on access, based on the International Code of Conduct for Plant Germplasm Collecting and Transfer.[88]

Asian scientists have prepared two declarations regarding the collecting, utilization and exchange of PGRFA; the Manila Declaration, which calls for the ethical collecting and utilization of Asian biological resources, and the Melaka Accord, which calls for the regulation of movement of plant genetic resources in the region.[89] The Philippines is one of the few countries which has formally introduced national regulations governing access to plant genetic resources (Box 5.2).

The countries of the Andean Pact agreed a common regime on access to genetic resources (Cartagena Agreement 391) on 17 July 1996.

### 5.4.2 Phytosanitary regulations[90]

The movement of plant germplasm can inadvertently spread pests and diseases. To reduce this risk, most countries have legislation to regulate the entry (and sometimes the internal movement) of plants, plant parts and their products. Consignments of germplasm infested with pests or diseases, plant species considered pests as well as material without proper documentation can be refused entry, destroyed or reconsigned. Phytosanitary regulations therefore have important implications for plant germplasm collecting, exchange, distribution and utilization.

Most countries are signatories to the International Plant Protection Convention (IPPC) under which there are eight regional organizations. Following the establishment of the World Trade Organization (WTO), IPPC is now being brought into line with WTO's Agreement on the Application of Sanitary and Phytosanitary Measures.

**Europe** In all European countries, the import and export of plant genetic resources, whether seed, whole plant or *in vitro,* is subject to quarantine regulations. Importation of plant material must comply with restrictions on quarantine pests and diseases, and exports must comply with the regulations of the recipient country. New regulations within the EU require, for a number of crops, that the seed supplier guarantee their freedom from quarantine pests and diseases. This may require genetic resources programmes to do more work on plant health screening in order to allow seed to be exported.[91]

**Near East** Most countries have established phytosanitary legislation for controlling the import and export of plant materials. These countries, in general, allow the transfer of plant material certified to be free of disease and infection, and there is no restriction on the import and export of *in vitro* plant material. Even when quarantine laws are strict, their application varies from country to country, and uncontrolled introduction of plant material may occur. Pakistan's economy, for instance, has suffered greatly as a result of introduced cotton and banana pests and diseases, due in part to its relaxation of quarantine measures. The application of phytosanitary laws varies also with the type of crop: the rules controlling cotton germplasm in Egypt are strict, as are those protecting citrus and date palm germplasm in Morocco.[92]

### Box 5.2 The Philippines Presidential Executive Order No. 247

On 18 May 1995, the Philippines adopted a Presidential Executive Order (E.O.) which regulates access to genetic resources. The E.O. consists of four basic elements:

(1) A system of mandatory Research Agreements between collectors and the government containing minimum terms concerning provision of information and samples, technology co-operation and benefit-sharing. Philippine academic and research institutions, government agencies and intergovernmental institutions such as international agricultural research centres are eligible for Academic Research Agreements (ARA). All research 'directly or indirectly intended for commercial purposes' requires the more stringent Commercial Research Agreement (CRA). All private persons and commercial firms, whether foreign or domestic, are legally presumed to have commercial motives and must obtain a CRA.

All Research Agreements require:

- a limit on the number of samples that may be collected and exported;
- a complete set of all specimens to be deposited with the Philippine National Museum;
- specimen and relevant data deposited abroad is to remain accessible to Philippine citizens;
- the Collector is to inform the Philippine government and affected local and indigenous communities if a commercial product is derived from its activities;
- payment of negotiated royalties on commercial use;
- involvement of Philippine scientists in research and collecting;
- a fixed fee to be paid to the Department of Environment and Natural Resources (DENR);
- in the case of endemic species, the technology to be made available without royalty.

(2) An Inter-Agency Committee (IAC) comprising the Departments of Environment and Natural Resources, Science and Technology, Agriculture and Health, the National Museum, two Philippine scientists, one biodiversity NGO and one People's Organization with membership representative of indigenous communities will consider, grant, monitor and enforce compliance with Research Agreements and co-ordinate further institutional, policy and technology development.

(3) Prior informed consent is required from concerned local and indigenous communities. Where collecting of materials is carried out within ancestral lands and domains of indigenous communities, their prior informed consent shall be obtained in accordance with their customary laws.

(4) Collecting must not harm the Philippines biodiversity, ecosystems or inhabitants, and must conform with laws and procedures such as environmental impact assessments and protected area management plans.

**Africa** Plant protection acts exist in almost all countries in Africa. Some have been in place for a long time: Kenya's legislation goes back to 1937, and the Sudan's is older still — 1913. Generally, such legislation does not impede the import or export of plant genetic resources. The majority of countries only require that an import permit be obtained from the government service concerned and a phytosanitary certificate issued. In some cases, a quarantine period is enforced by those responsible for plant protection, but such regulatory provisions are not always applied. Countries such as Côte d'Ivoire, Ghana, Nigeria, and the Indian Ocean Islands are active in implementing quarantine regulations, while others, such as Botswana, Namibia and the Niger, lack suitable quarantine facilities. In countries where quarantine regulations are not rigorously enforced, illegal import and export of wild plants may take place and diseased plant material may be introduced.

**Asia and the Pacific** Quarantine regulations are in place in the majority of the region's countries. In the Pacific, however, it is reported that such regulations are not always well enforced due to a general lack of awareness of the law's importance and lack of funds for monitoring the movement of material.[93] Member nations of the Association of Southeast Asian Nations (ASEAN) - Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam - have declared their combined territories a plant quarantine zone under the ASEAN-PLANTI network (Asian Plant Quarantine Centre and Training Institute, Malaysia), which regulates movement of plant materials within the sub-region. Individual countries have lists of plant species whose entry into the countries of the sub-region are restricted or banned as a threat of pest and disease introduction.[94]

**Americas** Quarantine regulations are in place in all countries, but their implementation varies from country to country. In Cuba, there are reports of germplasm losses during the quarantine process. In Ecuador, lack of funding restricts the efficiency of the quarantine service, and Guatemala and Nicaragua report problems in enforcing quarantine legislation.[95]

### 5.4.3 Seed regulations[96]

Seed certification is meant to ensure that the seed for sale is of the variety and quality named. In many countries, varieties cannot be sold unless certified. Moreover, they cannot be certified without going through the release procedures that place them on a national variety list. Registration in the EU, for instance, requires a variety to be distinct, homogeneous, stable and new.[97]

New improved varieties displace older cultivars from the catalogues; the latter are then no longer available on the market as they are not registered, and the seed is no longer certified and produced. In the United States, however, seed is sold subject only to a "truth in labelling" requirement. New Zealand, on the other hand, has no seed laws and successfully manages its seed industry entirely through voluntary certification.[98]

Laws relating to seed certification and licensing have been drawn up by several countries, Kenya for example, has the Seeds and Plant Varieties Act of 1972, Uganda the Agricultural Seeds and Plant Statute of 1994 and Ethiopia has its National Seed Policy. Seed legislation in Malawi, South Africa,the United Republic of Tanzania, Zambia and Zimbabwe provides for compulsory registration of cleaners, sellers and testers of seeds; the naming of varieties; seed quality and seed bulking requirements; regulations for the import and export of seeds etc. Other countries in the region do not have legislation governing the sale and distribution of seeds. Traditional varieties are conserved by farmers out of necessity and because it is their custom. There is no legislation regulating their sale and distribution.

Seed certification legislation has been adopted by most countries in the Near East region and by about half of the countries in Asia and the Pacific. In China, seed law recognizes breeders' rights and the contribution of genetic resources workers, and encourages the conservation and use of genetic resources.[99] In general, there are no mechanisms for variety registration and release or for seed certification in the Pacific region. In South and Southeast Asia, seed certification and variety release programmes exist in Malaysia, the Philippines, Thailand, Viet Nam, India, Bangladesh and Sri Lanka.

In some countries, changes in seed regulations have lagged behind changes in the seed sector, and it has been stated that seed regulatory systems may actually hinder the delivery of appropriate seed and crop varieties to the majority of developing country farmers.[100] There is an urgent need to develop seed certification and production systems (and appropriate regulations) that are aimed, specifically, at resource-poor farmers. These systems are based on community-level control of the seed production process[101] with appropriate institutional support.[102] For instance, in Nepal, a local-level seed production system assigns extension agents responsibility for maintaining seed standards,[103] while in Peru[104] and Zambia[105] "neighbour certified" seed schemes are being implemented.

Highly successful seed certification services have been developed in Bolivia with a multi-participant approach involving local seed producers, private companies, government programmes and NGOs.[106] FAO has recently developed a set of technical guidelines for the production of "quality declared" seed in situations with limited technical resources, for many cereals, food legumes, oil and forage crops, forage crops and industrial and vegetable crops.[107]

Increasingly, countries are realizing that variety release and seed certification legislation which includes requirements for distinctness, uniformity and stability can hinder the utilization of diverse genetic material, including the utilization of landraces. During the preparatory process, it was recommended that countries review their regulatory frameworks for their impact on the conservation and use of PGRFA, in order to promote flexibility of implementation and, if necessary, the creation of special categories to allow for the distribution and commercialization of landraces.[108]

Seed legislation in the EU, for example, is currently under review, to bring it in line with the reforms of the Common Agricultural Policy, to promote the use of traditional varieties. The EU Council of Ministers is discussing the possibility of permitting the marketing of old varieties in small seed lots; in Switzerland, seed law has already been modified along these lines.[109]

### 5.4.4 Plant breeders' rights

Forty countries have laws to protect plant breeders' rights. Thirty of these are members of the International Union for the Protection of New Varieties of Plants (UPOV) under the 1978 Convention (Figure 5.2).[110] These laws give breeders exclusive rights to market varieties they have bred for a period of time (usually 20 years). In general, these laws include "breeders' exemptions" which permit the use of protected varieties as genetic resources in further breeding. In many cases, the law also provides "farmers' exemptions" which allow farmers to save and reuse seed of protected varieties on their farms.

**Europe** In Western Europe, nearly all countries are members of UPOV. Most have also signed the 1991 Convention, although this is not yet in force. In addition, the EU has adopted Community Breeders' Rights legislation which applies to all member nations. A growing number of Eastern European countries adhere to the UPOV convention, and several have requested legal advice on these issues.[111]

**Near East** Morocco, the Islamic Republic of Iran and Pakistan are developing legislation.

## Global status of plant breeders' rights legislation

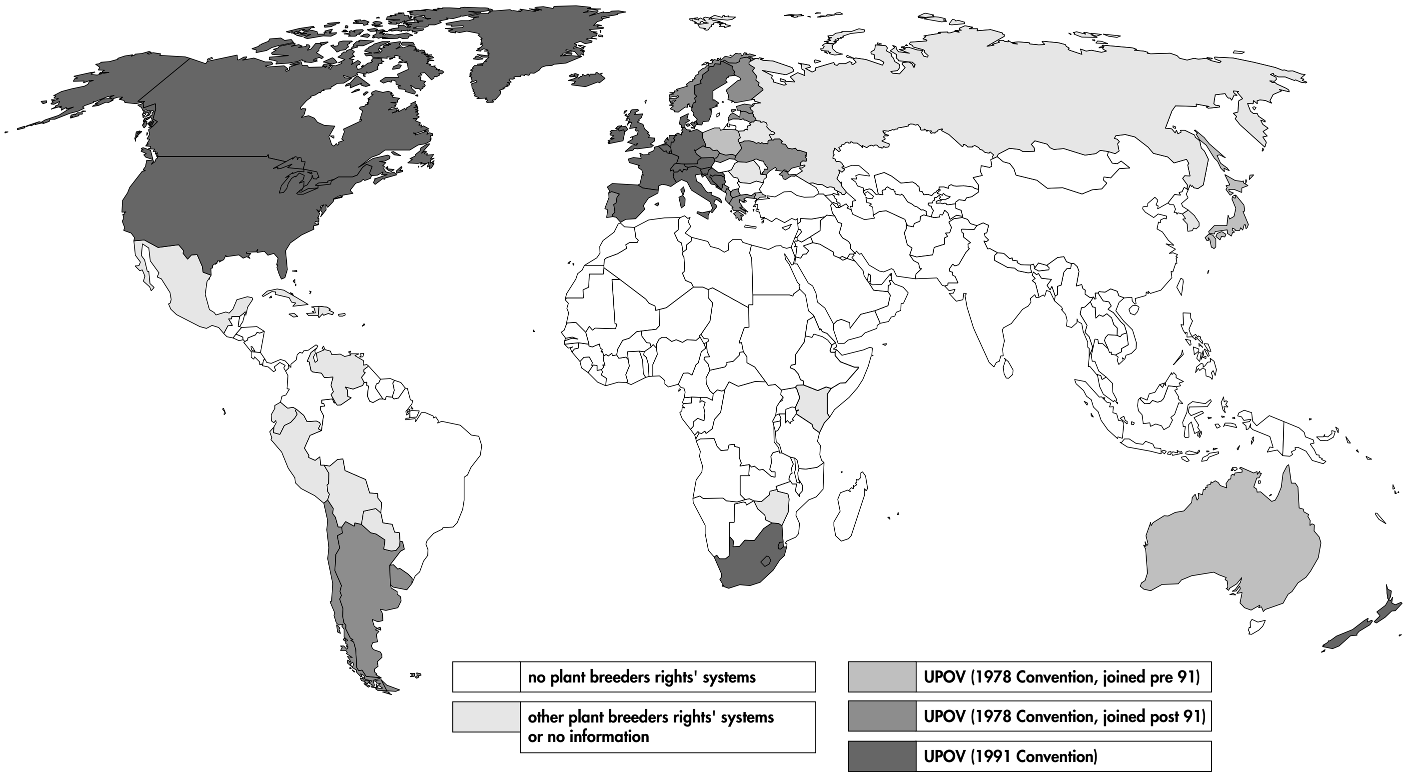



Figure 5.2

*Source:* Information provided by UPOV secretariat, February, 1996

**Africa** Only South Africa adheres to the UPOV Convention. Kenya and Zimbabwe have their own plant breeders' rights laws, and Zambia is in the process of developing legislation.

**Asia and the Pacific** Australia, Japan and New Zealand are members of UPOV, while the Republic of Korea has its own breeders' rights system. Other countries in the region do not have such legislation, although India and the Philippines are considering plant breeders' rights legislation which would reward the providers of genetic resources.

**Americas** Argentina, Canada, Chile, Uruguay and the United States also have plant breeders' rights legislation in accordance with UPOV. Mexico has indicated that it will develop such legislation. The countries of the Andean Pact have developed their own plant breeders' rights system[112], although some are also considering applying for membership in UPOV.

Member countries of the World Trade Organization will be obliged, in future, to adopt systems of intellectual property rights (IPR) to protect plant varieties, either through patents or through plant breeders' rights, in accordance with UPOV or through the elaboration of another effective *sui generis* system.[113] International legal assistance is required to draft suitable intellectual property legislation for plant varieties in line with international agreements and national needs.[114]

During the preparatory process, it was proposed that *sui generis* legislation be developed to allow countries to make more profitable use of their plant biodiversity, encourage agricultural research, respect the interests of farmers,[115] and take into account the possible effects of Intellectual Property Rights (IPRs) on the conservation and utilization of plant genetic resources.[116] India, for example, feels that Farmers' Rights, including the right to re-use saved seed, should be considered in formulating a *sui generis* system for the country (see also Chapter Seven).

## 5.4.5 Other policies which affect the conservation and utilization of PGRFA

### Trade agreements

Trade policies, such as those of the World Trade Organization, can have an impact on the use of plant genetic resources in a number of ways. Trade-related intellectual property rights agreements, increased agricultural competition between countries due to the reduction of subsidies, and the implementation of sanitary and phytosanitary measures may also have an impact.

These are generally available to both communal and commercial farmers. In Malawi, for example, farmers may obtain subsidies in the form of loans for inputs, but only for seeds of improved or pure varieties. Such policies can lead to a narrowing of the genetic base by reducing the diversity of seeds available to farmers.[117]

Governments do not usually provide farmers with incentives to conserve traditional varieties. The Tanzanian Government, however, is contemplating the establishment of a Farmers' Rights fund in recognition of the important role farmers play as the custodians of traditional plant cultivars.

Farmers can also obtain credit facilities from the Ministry of Agriculture through the Department of Cooperative Development to buy agricultural inputs. The United Republic of Tanzania's national seed policy calls for 5% of earnings from foundation seed sales to be given to the breeding programmes that developed the variety.[118]

In Europe, the conservation of agrobiodiversity on-farm is being considered by a number of countries in response to government and public interest in the "greening" of agriculture through the use of more traditional organic and inte-grated farming systems. NGOs have been especially active in promoting these systems which are well developed in Germany, the Nordic countries and Switzerland.[119] The EU has established a special action programme on agricultural production methods that are compatible with protecting the environment (Box 5.3).[120]

## 5.5 ASSESSMENT OF THE MAJOR NEEDS FOR NATIONAL PROGRAMME DEVELOPMENT, TRAINING AND LEGISLATION

### National programmes and co-ordination mechanisms

The successful conservation and sustainable utilization of PGRFA requires action by a wide range of people in each country - germplasm curators, breeders, scientists, farmers and their communities, extension agents, resource area managers, planners, policy-makers and NGOs - and strong planning, evaluation and co-ordination mechanisms at the national level to enable all to participate constructively. About 40% of all countries have national programmes and effective co-ordination mechanisms. In many countries, however, national programmes are limited in scope, focusing on *ex situ* conservation, with poor institutional linkages to utilization efforts. Aid programmes that provide funds for genebanks alone can exacerbate the problem.

The importance of strengthening national programmes for the conservation and sustainable use of PGRFA was highlighted during the preparatory process for the International Technical Conference. In particular, the following needs were identified:

- the establishment of national committees or other co-ordinating mechanisms in order to facilitate participation and cooperation between all stakeholders;
- the elaboration of national policies and strategies for PGRFA which are integrated with national development plans and encompass *ex situ* conservation and *in situ* conservation and utilization;
- a clear legal basis for national programmes; and
- adequate capacity and sustainable funding. Most countries, while they recognize the need for international financial support, agree that basic operating costs should be provided by governments.

### Box 5.3 EU legislation in support of on-farm conservation[121]

The EU has established legislation that promotes *in situ* conservation activities. Council Regulation (EEC) No 2078/92 "on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside" provides "aid for farmers who undertake: ... to use other farming practices compatible with the requirements of protection of the environment and natural resources, as well as maintenance of the countryside and the landscape, or to rear animals of local breeds in danger of extinction; ... to ensure the upkeep of abandoned farmlands or woodlands; ... to set aside farmland for at least 20 years with a view to its use for purposes connected with the environment, in particular for the establishment of biotope reserves or natural parks or for the protection of hydrological systems."

Other relevant EU legislation includes:

- Council Regulation (EEC) No. 2081/92 which protects geographical indications and designations of origin for agricultural products and foodstuffs.
- Council Regulation (EEC) No. 2082/92 which establishes a scheme for certifying specific character of agricultural products and foodstuffs. Food products that are made from landraces and old cultivars are offered special protection, provided the production is limited to a specific geographical origin, or the production is based on particular traditional raw materials.
- Regulation (EC) No. 1467/94 provides support for the conservation, characterization, collection and utilization of genetic resources in agriculture. The recording of traditional regional experiences and farmers' and horticulturists' knowledge and methods of cultivation (specific uses, processing, taste, etc.) are eligible activities.
- Council Regulation (EEC) No. 2328/91 "on improving the efficiency of agricultural structures" establishes measures to contribute to the safeguarding of the environment and the preservation of the countryside, including the long-term conservation of natural farming resources.

In addition, a Commission proposal currently under consideration by the Council and the European Parliament is to provide a legal basis for the conservation of genetic resources, in particular "on-farm conservation and sustainable utilization of plant genetic resources through the growing and marketing of landraces and varieties which are naturally adapted to the local and regional conditions and threatened by genetic erosion." This proposal aims at completing EU legislation on the marketing of plant propagating material.

### The public and private sectors, universities and NGOs

National programmes should facilitate the role of both the public and private sectors. While there may be a need to strengthen the private sector in many countries, continued and, if possible, increased funding of public sector activities are also required. The informal sector - farmers' and community organizations, NGOs, etc. - has a particular role to play in *in situ* conservation and development. Universities also have a key role to play, particularly with regard to research.

### Training

Lack of education and training capacity is cited as a major constraint to national programme development in 80% of the Country Reports submitted, and most of the sub-regional meetings identified support for training as a priority. While the lack of graduate training focused on PGRFA is evident worldwide, training is also required at every level, from the technical and the farmer level to policy-making and management. The development of training capabilities at the national and regional levels should help reduce costs. Modules on plant genetic resources within existing university courses are required at the national level, while at the regional level training is needed in the form of short, specialized courses. Special emphasis should be given to the training of trainers and to training for women. Graduate training could be enhanced through cooperation among institutions capable of providing such training, but incapable perhaps of sustaining complete, autonomous programmes. Existing programmes might be expanded through contacts with other institutions. Distance learning possibilities should also be explored.

### Legislation

While most countries have phytosanitary regulations, other legislation concerning PGRFA is often poorly understood, inadequately developed and implemented or non-existent. There is a general need to review and assess existing laws, and adapt these or develop new ones in line with each country's specific needs.[122] There is also a general need to harmonize national legislation, especially concerning access to genetic resources, Farmers' Rights and their relation to intellectual property rights.[123] International legal assistance is required by many countries in order to draft suitable legislation covering intellectual property rights for plant varieties in line with international agreements and national needs.

### Public awareness

Finally, public awareness, both of the importance of PGRFA and of the programmes needed for their conservation and utilization, is lacking in virtually all countries. All of the institutions and organizations concerned will need to share responsibility for raising public awareness at every level of society. Few national programmes, at present however, have the capacity or the funds to promote public awareness, a situation which is both a cause and an effect of current underinvestment in PGRFA.

■

## Chapter 5 endnotes

[1] Sometimes this has been through the convening of national workshops but, in virtually all countries, the compilation of Country Reports has been an important catalyst in clarifying national policies and needs, including the need for further cooperation and coordination.

[2] Information on national capacities for the conservation and use of plant genetic resources is given in Chapters 3 and 4 respectively.

[3] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, observation (a); Subregional preparatory meeting: Southern Africa Report, recommendation (i); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, recommendation 6; Subregional preparatory meeting: Mediterranean Report, para 17.

[4] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, observation (c); Subregional preparatory meeting: Southern Africa Report, recommendation (i); Subregional preparatory meeting: West and Central Africa Report, para 19.

[5] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(c); Subregional preparatory meeting: Mediterranean Report, para 16 ; Subregional preparatory meeting: West and Central Africa Report, para 18; Subregional preparatory meeting: Southern Africa Report, recommendation (i).

[6] Subregional preparatory meeting: East Asia Report, para 13; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(c); Subregional preparatory meeting: West and Central Africa Report, para 16; Subregional preparatory meeting: Southern Africa Report, recommendation (i).

[7] Subregional preparatory meeting: Europe Report, para 23(b); Subregional preparatory meeting: North America Report, recommendation 3; Subregional preparatory meeting: Mediterranean Report, para 25; Subregional preparatory meeting: West and Central Africa Report, para 30; Subregional preparatory meeting: South America Report, para 12; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, recommendation 6.

[8] Subregional preparatory meeting: Mediterranean Report, para 18; Subregional preparatory meeting: West and Central Africa Report, para 16; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(c).

[9] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(c); Subregional preparatory meeting: West and Central Africa Report, para 15.

[10] Subregional preparatory meeting: West and Central Africa Report, para 17.

[11] Subregional preparatory meeting: Mediterranean Report, para 16; Subregional preparatory meeting: Europe Report, para 23(b).

[12] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, para 17.

[13] These include the Nordic countries, which do not have national programmes *per se*, but share a centralized regional programme.

[14] Formerly, the Plant Genetic Resources Centre of Ethiopia.

[15] Subregional Synthesis Report: East Africa, para 28.

[16] Country Report India.

17 Subregional Synthesis Report: East Africa, para 27.

18 This information is based on 148 Country Reports. It might be assumed that most of the countries that did not provide reports do not have national plant genetic resources programmes.

19 Information from Country Reports.

20 Subregional preparatory meeting: Mediterranean Report, para 19.

21 Subregional Synthesis Report: Europe, para 35.

22 The following survey is based on information provided by countries during the preparatory process for the International Technical Conference. Information was generally not provided in a standard form and, therefore, the coverage may vary from region to region.

23 Subregional Synthesis Report: Europe, para 30.

24 Information from Country Reports and Subregional Synthesis Report: Europe, paras 24-26.

25 Subregional Synthesis Report: Europe, para 25.

26 Subregional Synthesis Report: Europe, para 27.

27 Subregional Synthesis Report: Europe, paras 28-29.

28 Subregional Synthesis Report: South and East Mediterranean, para 20; Subregional Synthesis Report: West Asia, para 28.

29 Subregional Synthesis Report: West Asia, paras 23-24; Country Report Israel.

30 Information from Sufian Sultan, Palestinian Institute for Arid Land and Environmental Studes.

31 Subregional Synthesis Report: Central Asia, Section A.

32 Information from Country Reports.

33 Subregional Synthesis Report: South and East Mediterranean, para 20.

34 Information from Country Reports.

35 Subregional Synthesis Report: Southern Africa, para 16.

36 Subregional Synthesis Report: Southern Africa, para 19.

37 Subregional Synthesis Report: East Africa, para 26.

38 Subregional Synthesis Report: East Africa, para 27.

39 Subregional Synthesis Report: East Africa, para 31.

40 Subregional Synthesis Report: Indian Ocean Islands, para 24.

41 Subregional Synthesis Report: Indian Ocean Islands, para 27.

42 Subregional Synthesis Report: West Africa, paras 26-27.

43 Subregional Synthesis Report: East Asia, para 16.

44 Subregional Synthesis Report: East Asia, para 13.

45 Subregional Synthesis Report: South Asia.

[46] Subregional Synthesis Report: South Asia.

[47] Subregional Synthesis Report: South Asia, para 2.2.

[48] Subregional Synthesis Report: Southeast Asia.

[49] Bryan Hacker, personal communication.

[50] Subregional preparatory meeting: West and Central Africa Report, para 17; Subregional preparatory meeting: Mediterranean Report, para 20; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(e); Subregional preparatory meeting: Southern Africa Report, para 12(x).

[51] Subregional Synthesis Report: West and Central Africa, para 35.

[52] Subregional Synthesis Report: East Africa, para 35.

[53] Subregional Synthesis Report: South and East Mediterranean, para 20; Subregional Synthesis Report: West Asia, para 28.

[54] Subregional Synthesis Report: Central Asia, para 4.

[55] Subregional Synthesis Report: South and East Mediterranean, para 26; Subregional Synthesis Report: West Asia, para 36.

[56] Subregional preparatory meeting: Mediterranean Report, para 26.

[57] Subregional preparatory meeting: Mediterranean Report, para 27.

[58] Vellve R (1992) *Saving the seed*. Earthscan, London; Subregional Synthesis Report: Europe, para 37.

[59] Country Report United States.

[60] Country Report Canada.

[61] Subregional preparatory meeting: West and Central Africa Report, para 22.

[62] Subregional Synthesis Report: Southern Africa, para 20.

[63] Subregional Synthesis Report: East Africa, para 36.

[64] IPGRI (1997) *Impact assessment - a review of the IPGRI programme*. Rome.

[65] Subregional Synthesis Report: East Africa, para 40.

[66] Subregional preparatory meeting: South and Southeast Asia and the Pacific Report, para 21.

[67] Op. cit., endnote 49.

[68] Country Report Angola.

[69] Information from Country Reports.

[70] Ibid.

[71] Subregional preparatory meeting: West and Central Africa Report, para 25; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (iv).

[72] Subregional preparatory meeting: West and Central Africa Report, paras 24-25.

[73] Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 10; West and Central Africa Report, para 25.

[74] Subregional preparatory meeting: East Asia Report, para 20; Subregional preparatory meeting: Central and West Asia Report, para 25; Country Report Germany.

[75] Subregional preparatory meeting: West and Central Africa Report, para 25; Subregional Synthesis Report: Southern Africa, para 90.

[76] Subregional preparatory meeting: West and Central Africa Report, para 26.

[77] Ibid.

[78] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (iv); Country Report France.

[79] Subregional preparatory meeting: Southern Africa Report, para 12; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14; Subregional preparatory meeting: West and Central Africa Report, paras 3, 4 and 18; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, para 24; Subregional preparatory meeting: North America Report, para 11; Subregional preparatory meeting: South America Report, para 16; Subregional preparatory meeting: Mediterranean Report, paras 14, 18 and 27.

[80] Subregional Synthesis Report: East Africa, para 50.

[81] Subregional preparatory meeting: West and Central Africa Report, para 19.

[82] Subregional preparatory meeting: West and Central Africa Report, para 20.

[83] Ibid.

[84] Country Report United States.

[85] Subregional Synthesis Report: Europe, para 38.

[86] AMCEN (1994) *Common position and perspective on the Convention on Biological Diversity.*

[87] The common position recommends "a temporary ban on the transfer, from [African] countries, of any biological resources not covered by existing Conventions and where Prior Informed Consent is not in effect". Article 24 (c).

[88] Country Report Angola.

[89] Subregional Synthesis Report: Southeast Asia.

[90] Information from Subregional Synthesis Reports and Country Reports.

[91] Subregional Synthesis Report: Europe, para 42.

[92] Subregional Synthesis Report: South and East Mediterranean, para 24; Subregional Synthesis Report: West Asia, para 31.

[93] Subregional Synthesis Report: Pacific, Section II A.

[94] Subregional Synthesis Report: Southeast Asia, Section II A.

[95] Information from Country Reports.

[96] Information from Country Reports and Subregional Synthesis Reports.

[97] The European Union, however, allows ecotypes of forage crops to be marketed.

[98] Hampton JG and Scott DJ (1990) *New Zealand Seed Certification Plant Varieties and Seeds,* 3:173-180.

[99] Subregional Synthesis Report: East Asia, para 21.

[100] Tripp R (1995) *Seed regulatory frameworks and resource-poor farmers: a literature review*. Agricultural Administration (Research and Extension) Network Paper No. 51. Overseas Development Institute, London.

[101] Cromwell E and Wiggins S (1993) *Sowing beyond the state*. Overseas Development Institute, London.

[102] Farrington J and Bebbington AJ (1993) *Reluctant partners? Non-governmental organizations, the state and sustainable agricultural development*. Routledge, London and New York.

[103] Bal SS and Rajbhandary KL (1987) A model for seed production in remote areas of Nepal. *Seed Science and Technology*, 15:625-632.

[104] Scheidegger U, Prain G, Ezeta F and Vittorelli C (1989) *Linking formal research and development to indigenous systems: a user-oriented potato seed programme for Peru*. Agricultural Administration (Research and Extension) Network Paper No. 10. Overseas Development Institute, London.

[105] Lof H and Nchemba A (1994) *Seed banks: enhancement of farmers' control over seed supply*. Paper presented at second SADC Seminar on Seed Research and Certification, 17-20 May 1994, Maseru, Lesotho.

[106] Garay A, Pattie P, Landivar J and Rosales J (1988) *Setting a seed industry in motion: A non-conventional successful approach in a developing country*. Working Document No. 57. CIAT, Colombia.

[107] FAO (1993) *Quality declared Seed*. Plant Production and Protection Paper No. 117. Rome, 186 pp.

[108] Subregional preparatory meeting: Mediterranean Report, para 42.

[109] Subregional Synthesis Report: Europe, para 40.

[110] Except for Spain and Belgium which are members under the 1961 Convention.

[111] Subregional Synthesis Report: Europe, para 41.

[112] Régimen Común de Protección alos derechos de los Obtentores de Variedades Vegetales. Decisión 345. Del Acuerdo de Cartagena. Gaceta Oficinal Año X, No. 142, Lima, 29 Octubre 1993.

[113] Agreement on trade-related intellectual property rights of the World Trade Organization; Subregional Synthesis Report: West Africa, para 40.

[114] Subregional preparatory meeting: West and Central Africa Report, para 21.

[115] Ibid.

[116] Subregional preparatory meeting: Mediterranean Report, para 43.

[117] Subregional Synthesis Report: Southern Africa, para 28.

[118] Subregional Synthesis Report: Southern Africa, para 30.

[119] Subregional Synthesis Report: Europe, para 37.

[120] EEC Council Regulation No. 2078/92.

[121] Subregional preparatory meeting: Europe Report, Annex VII: A preliminary list of EU legislation in the area of plant genetic resources.

[122] Subregional preparatory meeting: West and Central Africa Report, para 20.

[123] Subregional preparatory meeting: South America Report, para 16(k).

# CHAPTER 6
# The State of Regional and International Collaboration

## 6.1 INTRODUCTION

In adopting Agenda 21, countries recognized the importance of international collaboration for the conservation and sustainable utilization of plant genetic resources for food and agriculture (PGRFA), and for the fair and equitable sharing of benefits derived from the use of these resources.[1] During the preparatory process for the International Technical Conference, the interdependency of countries with regard to PGRFA[2] was acknowledged, as was the need for a Global Plan of Action to provide international financial and technical support for PGRFA activities and training.

Within regions and sub-regions, countries usually have many crops and much plant genetic diversity in common. For this reason, their national PGRFA programmes often have similar objectives, and the value of sub-regional and regional collaboration, and the need to strengthen such collaboration, are widely recognized.[3]

The grouping of countries into regions, and the division of these into sub-regions, have been important factors in organizing the preparatory work for the International Technical Conference. The use of regions and sub-regions as working units in the lead-up to the Conference has indeed helped to encourage dialogue and reinforce collaboration. Sub-regions were delimited according to two criteria: the bringing together of countries with common indigenous plant genetic resources and agro-ecological conditions, and the coincidence of country groupings with actual or potential mechanisms for cooperation. A series of sub-regional meetings were held in 1995 to finalize sub-regional Synthesis Reports on the state of conservation and utilization of plant genetic resources in the respective sub-regions and to formulate regional-level recommendations for the Global Plan of Action.

Given the interdependence of regions for PGRFA, and the nature of PGRFA as a public good,[4] collaboration at the international level is vital. In this Chapter the following aspects of cooperation at the sub-regional, regional and global levels are reviewed:

- the status of, and further need for, collaboration at the sub-regional and regional levels, with particular emphasis on the role of sub-regional and regional PGRFA networks and crop networks, and on the need for collaboration in the area of *ex situ* conservation;
- international collaborative programmes, including those of FAO, CGIAR and other international organizations, bilateral programmes, foundations and NGOs;
- the role of the Convention on Biological Diversity and other international agreements;
- the role of the Global System on Conservation and Sustainable Use of PGRFA.

The Chapter concludes with a summary of major needs required to improve international collaboration.

## 6.2 COLLABORATION AT REGIONAL AND SUB-REGIONAL LEVELS

During the preparatory process for the International Technical Conference, the following objectives were identified for collaboration at the regional or sub-regional level:

- strengthen national PGRFA programmes;[5]
- avoid unnecessary duplication of activities in countries within the same region or sub-region;[6]
- share in PGRFA conservation and promote the exchange of genetic material;[7]
- exchange information, experiences and technology related to PGRFA conservation and utilization;[8]
- promote collaborative research;[9]
- promote the evaluation and utilization of conserved material;[10]
- co-ordinate research within regions, including regional and sub-regional programmes of the International Agricultural Research Centres (IARCs);[11]
- identify and promote opportunities for collaboration in training and capacity-building at sub-regional and regional levels;[12]
- formulate proposals for regional projects.[13]

### 6.2.1 Regional and sub-regional networks

Many of the above objectives can be promoted through regional or sub-regional PGRFA networks. There are several existing networks, but new networks need to be established in some parts of the world (Table 6.1) within the context of existing agricultural research networks and intergovernmental forums.[14] It should be emphasized, however, that, in order to be sustainable, collaboration must be based on sound national programmes.

The development of efficient systems of documentation and communication was highlighted as a priority function for sub-regional networks. The meeting for West and Central Africa highlighted a particular need for databases with information on the *in situ* and *ex situ* germplasm that is available in the region, and for a sub-regional newsletter as well as translations of information into the languages of the regions.[15]

## Table 6.1 Regional and subregional PGRFA networks

| Region | Subregion | Existing PGRFA networks | Status and comments |
|---|---|---|---|
| **Europe** | | | |
| | Western Europe | ECP/GR | Very well-developed network; self-financing |
| | Eastern Europe | | Most countries of the region are members |
| **Near East** | | | |
| | Southeast Mediterran. | | Well-developed network; links with ECP/GR need to be strengthened (e.g. in Mediterranean) |
| | West Asia | WANANET | 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 |
| **Sub-Saharan Africa** | | | |
| | Southern Africa | SPGRC | Well-developed network; all countries of the region are members; partially self-financed |
| | Central Africa | __ | Network for West and Central Africa proposed in context of existing organizations |
| | West Africa | | |
| | East Africa | __ | Need for closer cooperation identified |
| | Indian Ocean | | |
| **Asia / Pacific** | | | |
| | South Asia | S.As./PGRN | Formal network is being established |
| | Southeast 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 |
| | | ANZNPGRC | Coordinated network for Australia and New Zealand |
| **Americas** | | | |
| | South America | TROPIGEN<br>REDARFIT<br>Procisur-RF | Well-established networks, agro-ecologically based; all countries members of one or more |
| | C. Am. and Mexico | REMERFI | Well-established network |
| | Caribbean | CMPGR | New network, mostly focused on anglophone countries; need to integrate with hispanophone and francophone countries |
| | North America | __ | Good bilateral links |

## 6.2.2 Crop-specific networks

The need to establish or strengthen crop-specific working groups, in order to improve conservation and utilization and facilitate the exchange of germplasm, information and technologies, was also identified during the preparatory process.[16] Crop networks are an excellent means of bringing together specialists from different fields on an international or regional basis to set priorities for a particular crop's genetic resources. This usually involves formation of a shared database of all accessions in *ex situ* collections, the strengthening of collaboration in collecting and evaluation of germplasm, and the promotion of more effective utilization of crop genetic resources.

## 6.2.3 Regional review of plant genetic resources networks and associated crop networks

**Europe** The main plant genetic resources network in Europe is the European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), a collaborative programme aimed at ensuring the long-term conservation and increased use of plant genetic resources in Europe. The Programme, originally established by FAO, is entirely financed by participating countries and is governed by a steering committee of national representatives with overall co-ordination provided by the International Plant Genetic Resources Institute (IPGRI). It operates through crop-specific working groups in which curators and breeders, representing their respective countries, work together to analyse needs and set priorities for the crop concerned. Currently, seven crop working groups are active: *Allium*, *Avena*, barley, *Brassica*, forages, *Prunus* and grain legumes. A group on *Malus* is also planned. At the regional meeting in preparation for the International Technical Conference, it was proposed that ECP/GR be used to facilitate implementation of the Global Plan of Action for the Europe region.[17]

The European Forest Genetic Resources Programme (EUFORGEN) is a collaborative programme among European countries aimed at ensuring the long term conservation and the sustainable utilization of forest genetic resources in Europe. It was established to implement Resolution 2 of the Strasbourg Ministerial Conference on the Protection of Forests in Europe. EUFORGEN is financed by participating countries and is co-ordinated by IPGRI, in collaboration with the Forestry Department of FAO. It facilitates the dissemination of information and various collaborative initiatives. The programme operates through networks in which forest geneticists and other forestry specialists work together to analyse needs, exchange experiences and develop conservation objectives and methods for selected species. The networks also contribute to the development of overall conservation strategies for the ecosystems to which these species belong.

Network members and other scientists and forest managers from participating countries carry out an agreed work plan with their own resources as in kind inputs to the Programme. EUFORGEN is overseen by a Steering Committee composed of National Coordinators nominated by the participating countries.

The other major network of relevance to PGRFA in the region is the European System of Cooperative Research Networks in Agriculture (ESCORENA), established by FAO in 1974 upon the recommendation of the European Commission on Agriculture. Within this programme, ten crop-specific networks and three ad hoc research groups are concerned with plant genetic resources. According to Country Reports, the ESCORENA networks most concerned with genetic resources are those for flax,[18] olives,[19] soybean[20] and sub-tropical fruits.[21] The mandates of many of these networks are being expanded (Section 6.3.1).

Within the European Union, the European Programme for Conservation, Characterization, Collection and Utilization of Genetic Resources in Agriculture (EC 1467/94) has been established to help ensure and improve the conservation, characterization, documentation, evaluation, collection and utilization of potentially valuable plant and animal genetic resources in the European Community.

During the sub-regional meeting for the Mediterranean, it was emphasized that countries bordering all sides of the Mediterranean face similar problems with regard to conservation and use of PGRFA.[22] Participants agreed on the need to strengthen inter-regional co-operation in the area in order to set priorities and reduce wasteful duplication of activities. Co-operation should include links between relevant networks in Europe and the Near East.[23] An Italian-funded project on the conservation and use of under-utilized Mediterranean species has networking activities for pistachio, rocket, oregano and hulled wheat, involving institutions in Europe, North Africa and West Asia.

**Near East** The West Asia and North Africa Plant Genetic Resources Network (WANANET) is the main plant genetic resources network in the Near East. It has helped to strengthen national programmes by reinforcing the role of national plant genetic resources committees and by promoting co-operation between institutions within countries and programmes within the sub-region.[24] WANANET was created in 1992, the result of collaboration between the countries and IPGRI (WANA Group), ACSAD, FAO and ICARDA. Currently, 14 countries (Algeria, Cyprus, Egypt, Iraq, the Islamic Republic of Iran, Jordan, Lebanon, Libyan Arab Jamahirija, Morocco, Pakistan, Tunisia, Turkey, the Syrian Arab Republic, and Yemen) participate in the network which has established working groups for cereals, food legumes, pasture, forage and rangeland, industrial and horticultural crops, as well as for *in situ* conservation.

The former Central Asian Republics of the Soviet Union are not yet incorporated in a plant genetic resources network. Prior to independence, most collaborative links were with other Soviet Republics through the Vavilov Institute. During the sub-regional meeting for Central and Western Asia, it was recommended that a network for these countries, in association with WANANET and ECP/GR, be established.[25]

**Africa** The only operational sub-regional plant genetic resources network in the region is the Southern Africa Development Community (SADC) Plant Genetic Resources Centre (SPGRC), established within the framework of the Southern African Centre for Co-operation in Agricultural and Natural Resources Research and Training (SACCAR), the institution co-ordinating agricultural and national resources research in SADC. The primary objective of SPGRC is to establish, over a 20-year period, a regional plant genetic resources centre in Lusaka, Zambia, and a network of national plant genetic resources centres in each SADC member country,[26] in order to conserve indigenous plant genetic resources within the region, provide training in plant genetic resources and promote germplasm collection, characterization, documentation and utilization.

While most funding is provided by the Nordic countries, a proportion is contributed by member countries. SPGRC, with its links to agricultural research networks, is a useful and functional model programme for sub-regional collaboration, and the strengthening of national activities.[27]

SACCAR also oversees crop-specific networks which aim to develop, through research and training, locally adapted, improved crop varieties. The networks are facilitated by the international agricultural research institutions indicated below:

- sorghum and millet improvement programme - International Crops Research Institute for the Semi-Arid Tropics (ICRISAT);
- regional groundnut and regional pigeon pea programmes - ICRISAT;
- regional root crops and regional cowpea programmes - the International Institute of Tropical Agriculture (IITA);
- regional agroforestry projects in four SADC member countries - the International Center for Research in Agroforestry (ICRAF);
- wheat and maize networks in most member countries - Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT);
- bean research network - Centro Internacional de Agricultura Tropical (CIAT);
- regional vegetable research and training project - the Asian Vegetable Research and Development Centre (AVRDC).

Another important project in the sub-region is the SADC Tree Seed Centre Project sponsored by the Canadian International Development Agency (CIDA). Most SADC countries are participants in this sub-regional initiative, whose main objective is to bring about national self-sufficiency in quality seeds for both exotic and indigenous species.

There is no specific sub-regional plant genetic resources network for East Africa. Cooperation could be promoted within the context of the Association of Agricultural Research in East and Central Africa (ASARECA) which is the main agricultural research network in the region.

Other relevant bodies include the African Biodiversity Network of the African Ministerial Conference on the Environment, the Inter-Governmental Authority on Drought and Development (IGADD) and the Regional Agricultural Research Programme for Zaire, Rwanda, and Burundi.

There are, however, many crop-specific networks and networks for groups of crops, operating in East Africa, most of which were initiated and developed by the IARCs.[28] These include:

- the Potato and Sweet Potato Improvement Network for Central and Eastern Africa (PRAPACE) co-ordinated by the Centro Internacional de la Papa (CIP);
- the East African Root Crops Research Network (EARRNET) co-ordinated by IITA;
- Eastern Africa Research on Sorghum and Millet Network (EARSMN) co-ordinated by ICRISAT;
- the East African Regional Cooperative for Research on Banana and *Enset* (EARCORBE) co-ordinated by the International Network for the Improvement of Bananas and Plantains (INIBAP);
- the Great Lakes Regional Bean Programme (RESAPAC) co-ordinated by CIAT;
- the Agroforestry Research Network for the Highlands of East and Central Africa (AFRENA) co-ordinated by ICRAF;
- the Alley Farming Network for Tropical Africa (AFNETA) co-ordinated by IITA.

In addition, the Southern and Eastern African Network on Under-utilized Crops (SEANUC) was established in 1995 as a result of cooperation between the Commonwealth Science Council, the International Centre for Under-utilized Crops and FAO.

There is no specific plant genetic resources network for the Indian Ocean Islands, though discussions are under way to develop one within the framework of the Indian Ocean Commission.

In West and Central Africa, there are no specific plant genetic resources networks. Some crop networks, however, of the Conference of Directors of Agronomic Research in West and Central Africa (CORAF), the sub-region's main agricultural research network, have the capacity to undertake plant genetic resources activities. These include networks for peanuts, cotton, cassava, maize and rice.

At the sub-regional meeting for West and Central Africa, it was agreed, that a sub-regional network be established within the framework of existing organizations.[29] In addition, the IARCs co-ordinate networks in West and Central Africa.

These include:

- ROCAFREMI and ROCARS for millet and sorghum, respectively, co-ordinated by ICRISAT;
- the African Yam Networks and the Regional Research Project for Maize and Cassava for West and Central Africa co-ordinated by IITA;
- the West Africa Rice Development Association (WARDA), a unique institution in the sense that it is one of the few CGIAR centres whose mandate is exclusively regional.

The French organizations, the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) also have major programmes throughout West and Central Africa.

**Asia and the Pacific** The four sub-regional plant genetic resources networks for Southeast Asia, South Asia, East Asia and the Pacific are at various stages of development. The most developed is the Regional Collaboration in Southeast Asia on Plant Genetic Resources (RECSEA-PGR), formally established in 1993. Its members are Indonesia, Malaysia, Papua New Guinea, the Philippines, Thailand and Viet Nam.

RECSEA-PGR has identified the establishment of a sub-regional network information system, and on-farm conservation as its priority areas, for which greater financial support is needed however. Other networks in Southeast Asia include the following:

- the Plant Resources of South East Asia (PROSEA) in which Indonesia, Malaysia, Papua New Guinea, The Philippines, Thailand, Viet Nam and the Netherlands collaborate in order to collate and document the wealth of existing information on plant genetic resources in the sub-region. Its two main objectives are to publish an updated 22-volume handbook on the plant resources of Southeast Asia, and to build a database of plant resources publications;
- the Southeast Asian Programme for Potato Research and Development (SAPPRAD) which co-ordinates training, crop improvement and varietal testing for potato and sweet potato;
- the User's Perspective with Agricultural Research and Development (UPWARD) programme which aims to collect the wide range of sweet potato germplasm and associated indigenous knowledge in the sub-region.

The National Coordinators of South Asian countries met in 1990, 1992 and 1995 to stimulate collaboration in the sub-region. A plant genetic resources network for South Asia is now formally being established. The formation of a plant genetic resources network for East Asia was strongly recommended by the sub-region's National Coordinators at their meeting in 1994. A plant genetic resources network for the Pacific sub-region is also being initiated with support from IPGRI, the South Pacific Regional Environmental Programme, the South Pacific Commission, and the University of the South Pacific. A number of plant genetic resources activities are already being carried out within other cooperative programmes. Examples are:

- the Pacific Agricultural Research Programme, which includes the establishment of a collection of sweet potato germplasm and the selection, evaluation and distribution of superior genotypes to member countries;
- the South Pacific Regional Environment Programme (SPREP) which co-ordinates research on conservation and the sustainable use of biodiversity, especially forest species;
- the South Pacific Commission (SPC) which, through its Agriculture Division, has been active in collaborating with member countries in the collection and conservation of root crop genetic resources.

Other countries in the sub-region have collaborative programmes with the IARCs as well as the Australian Council for International Agricultural Research (ACIAR).

The nine plant genetic resource centres which support national programmes and contribute to international plant improvement programmes are linked in a network through the Australian and New Zealand Network of Plant Genetic Resource Centres (ANZNPGRC). This has a coordinating function, promoting linkage between centres.

The sub-regional meetings in the region recommended stronger collaboration between sub-regions and the establishment of a regional network within which the sub-regional networks would operate.[30] Also at the regional level, FAO has established the Asia Pacific Seed Association (APSA) which has 150 private and public sector seed programmes members. Additionally, the Under-utilized Tropical Fruit Trees Network (UFTANET) was established in 1994 with the aim of promoting the conservation, utilization and improvement of fruit production in Asia. Twelve national programmes, ICUC, FAO, and IPGRI are collaborating in this network.

**Americas** Three sub-regional plant genetic resources networks cover South America according to its three agro-ecological zones. A network also exists in Central America and Mexico, and one is being established in the Caribbean. No formal network exists in North America, but there are good bilateral contacts between Canada and the United States. The sub-regional networks operate within the framework of the cooperative agricultural research networks of the Inter-American Institute for Co-operation on Agriculture (IICA). They are supported by IICA, IPGRI, FAO and, where appropriate, from the Centro Agronónomico Tropical de Investigación y Enseñanza (CATIE). SELA (Sistema Economico Latinoamericano) has established an action committee for plant genetic resources, which has carried out a study on the collection, conservation and use of plant genetic resources in the region. At the regional meeting for Latin America and the Caribbean (Bogota), it was recommended that a forum be established to discuss conservation, utilization and the sharing of benefits derived from PGRFA, and to facilitate a common regional perspective.

The three networks for the three agricultural zones in South America are:

- REDARFIT, the Andean Plant Genetic Resources Network;
- TROPIGEN, the Amazonian Plant Genetic Resources Network; and
- the network of PROCISUR, the Programa Cooperativo para el Desarrollo Tecnológico Agropecuario del Cono Sur.

In Central America, the Red Mesoamericana de Recursos Fitogenéticos (REMERFI) is a well established network, and participants at the sub-regional meeting for Central America, Mexico and the Caribbean recommended that it be given responsibility for monitoring, supervising and coordinating cooperative activities.[31] Collaboration between countries in the Caribbean, however, is not fully developed, partly due to language differences. The country with the most developed plant genetic resources programme is Cuba. The Caribbean Committee on Management of Plant Genetic Resources has been set up in an attempt to create a programme comprising the entire Caribbean. Without financial and technical support, however, its activities are limited. Most English-speaking countries in the Caribbean which are members of the Caribbean Economic Community (CARICOM) are served by the Caribbean Agricultural Research and Development Institute (CARDI) and the University of the West Indies. Within the CARICOM group, the smaller island states are well integrated through the Organization of the Eastern Caribbean States (OECS). At a meeting organized during the preparatory process for the International Technical Conference, the OECS countries recommended the formulation of a cooperative programme on plant genetic resources with a particular emphasis on training, *in situ* conservation and the economic development of under-utilized species.[32]

FAO also carries out sub-regional activities related to plant genetic resources through a project entitled *Improved Seed Production in the CARICOM Countries.*[33] This project includes training in seed technology, elaboration of a regional seed quality standard and the establishment of the Caribbean Seed and Germplasm Resources Information Network (CSEGRIN).

The following crop networks operate in Latin America and the Caribbean, some on a sub-regional and others on a regional basis:

- Profrijol and Profiza, networks for the evaluation, improvement and utilization of beans for Central America and the Andean zone, respectively, co-ordinated by CIAT;
- Precodepa, Procipa and Pracipa, sub-regional potato networks for germplasm evaluation in Central America and the Caribbean, the Southern Cone countries, and the Andean region, respectively, co-ordinated by CIP;
- Procacao and Promecafe, networks formed for the improvement and utilization of cacao and coffee respectively, co-ordinated by IICA and CATIE and supported financially by the Inter American Development Bank (IADB);
- Latin America Maize Programme (LAMP), a network for germplasm evaluation and regeneration supported by USDA/ARS, Pioneer Hi-Bred International, and national programmes (Box 6.1).

In addition, FAO co-ordinates, through its regional office for Latin America and the Caribbean, a Technical Cooperation Network on Plant Biotechnology (REDBIO) for the exchange of information on tissue culture and other biotechnological techniques.

### 6.2.4 Sub-regional collaboration for *ex situ* collections

During the preparatory process, the desirability of countries sharing the burden and costs of conservation was noted.[34] At the Mediterranean meeting, it was agreed that the development of regional or sub-regional genebanks might provide an alternative to building national genebanks, especially for the conservation of duplicate base collections, an idea brought up at other meetings as well.[35] Countries also recognized the important role of the International Network of *Ex situ* Collections under the auspices of FAO in this regard (see Section 6.5.2).[36]

In some regions, countries have established central genebanks to act as sub-regional base collections. The Nordic Gene Bank holds accessions for Denmark, Finland, Iceland, Norway, and Sweden, as these countries do not keep individual

**Box 6.1 Regeneration of Latin American maize through LAMP**

Maize is the most important grain crop in Latin America and a major export crop of the United States. The large size of the seed makes it difficult to dehydrate for long-term storage in genebanks, and the accessions require regeneration more frequently than most smaller grains. Twelve maize-breeding countries in the Americas agreed to collaborate in a germplasm project called the Latin American Maize Project (LAMP). Pioneer Hi-Bred International provided $1.5 million and technical inputs in support of this project coordinated by the USDA. LAMP has been a highly successful initiative in regional collaboration to improve the conservation and use of maize genetic resources. While the main objective of the programme was to evaluate for future use the agronomic characteristics of maize accessions in germplasm banks in Latin America and the United States, a number of secondary objectives were also set:

- determine the exact number of accessions in each bank;
- identify the amount and quality of seed in each accession;
- list accessions that are in need of regeneration.

In response to the information on regeneration needs, a subsidiary project entitled *Regenerating Endangered Latin American Maize Germplasm* was developed by USAID, USDA and CIMMYT to salvage maize holdings in Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Mexico, Peru and Venezuela. These 13 countries are participating in the regeneration of nearly 10,000 endangered landrace accessions. Newly regenerated material is conserved in the national collections, with samples duplicated at CIMMYT and/or NSSL.

national collections. For Southern Africa, it is proposed that SPGRC hold the base collections of countries in the region, while national centres hold active collections. The regional genebank for Central America and Mexico, financed by the German Ministry for Economic Cooperation and Development (BMZ), handled through the German Agency for Technical Cooperation (GTZ) and located at CATIE, is based on an existing *ex situ* plant genetic resources collection established earlier by researchers from IICA. In addition, other international organizations hold germplasm collections for particular crops which complement the collections of individual countries.

Participants at the sub-regional meeting for West and Central Africa gave high priority to the creation of a sub-regional genebank.[37] It was also 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, through one or another of the following models:[38]

- a central sub-regional base collection which would also support national programmes (e.g. SPGRC in Southern Africa);
- the use of existing national genebanks to hold material on behalf of other countries in the sub-region with appropriate legal arrangements where necessary (e.g. the role of Ethiopian and Kenyan genebanks in East Africa);
- a network of national genebanks, each one specializing in a particular species or group of species according to mandates agreed upon by the participating countries (a system like this was proposed for North Africa).

The above would necessitate the drawing up of model legal agreements to cover situations where a country's collection, or part of it, is stored in another country, in order to ensure that the country's sovereign rights over its genetic resources are respected, and to ensure that material is made readily available upon request.[39]

During the preparatory process, some countries offered to make their *ex situ* conservation facilities available for the safe-keeping of material from other countries, or to host sub-regional facilities, subject to satisfactory arrangements being agreed upon. These countries included the Islamic Republic of Iran, Pakistan and Turkey for Central Asia; India for Asia and the Pacific; Argentina, Brazil, Ecuador and Chile for South America; and China for East Asia and other countries.[40] Similar offers were made at a global level by Argentina, Norway, Spain and the United States, within the context of the International Network of *Ex Situ* Collections under the auspices of FAO.

## 6.3 INTERNATIONAL PROGRAMMES

### 6.3.1 FAO

FAO's mandate in the field of genetic resources is encompassed by its constitutional responsibility "to promote national and international action for the conservation of natural resources and the adoption of improved methods of agricultural production". FAO's regular programme, particularly through its Departments of Agriculture and Forestry, covers a wide range of activities related to plant genetic resources. Through its regular programme, FAO hosts the Secretariat for the Commission on Genetic Resources for Food and Agriculture, supports other components of the Global System on the Conservation and Utilization of PGRFA (see Section 6.5), and provides support for national capacity-building in plant genetic resources conservation, plant breeding, seed production and distribution, and related legal and policy work. In addition, FAO's biotechnology programme is increasingly relevant to the conservation and utilization of PGRFA (Box 6.2).

**Box 6.2 International co-operation and biotechnology transfer**[41]

There are an increasing number of international plant biotechnology programmes.[42] Many are primarily concerned with crop research, but some focus on related aspects such as priority-setting and research management, product development, technology assessment and transfer, biosafety and intellectual property rights.[43]

Agricultural biotechnology transfer programmes vary in their approach; most are technology-driven[44] but demand-driven participatory technology development approaches have recently emerged.[45] Some examples of this are the UNDP/FAO Agricultural Resource Management programme[46] which works with poor farmers[47] to identify appropriate biotechnologies, and the biovillage concept of the M.S. Swaminathan Research Foundation in India which attempts to diffuse appropriate biotechnologies in rural areas.[48] Another approach, promoted by ISAAA, involves acting as an "honest broker" to match proprietary agricultural biotechnologies with the needs of developing countries.[49]

In recent years, a number of international organizations, including the Intermediary Biotechnology Service (IBS),[50] OECD,[51] UNESCO[52] and ILO,[53] have begun to assess biotechnology in relation to its potential socioeconomic impact. Other organizations, including the African Centre for Technology Studies (ACTS) in Kenya, help develop policy formulation capacity and advise countries on appropriate biotechnology policies. RIS in India, for example, provides information on economic issues related to biotechnology; RAFI monitors biotechnology developments for their potential negative environmental or socioeconomic impact,[54] and the International Development Research Centre (IDRC), in Canada, operates joint programmes with Latin American countries to assess the potential impact of biotechnologies. In addition, both the International Programme on Rice Biotechnology[55] and the Cassava Biotechnology Network[56] contain modules on impact assessment.

A recent survey of 45 organizations involved in the transfer of agricultural biotechnology revealed that most initiatives concentrate on the few developing countries with relatively advanced scientific and technological capabilities,[57] and that developing country scientists and administrators are not always directly involved in their planning and design.[58]

FAO's Field Programme has carried out a large number of projects and programmes in developing countries related to the conservation and utilization of plant genetic resources, many of which have been financed by UNDP and the World Bank. A comprehensive report on FAO's activities is periodically submitted to the Commission on Genetic Resources for Food and Agriculture.[59]

FAO has played a key role, in collaboration with other organizations, in setting up many of the regional and sub-regional networks reviewed in this chapter. FAO has also developed a number of crop-specific and crop group networks, particularly for crops which are outside the mandate of the IARCs and, therefore, unlikely to receive sufficient attention. These include the International Mushroom Germplasm Conservation Network and the International Network on Cactus Pear. The mandates of several of the crop-specific networks developed by FAO within the framework of ESCORENA are also being broadened. This applies to the Olive Genetic Variability Network (a working group under the existing ESCORENA Olive Network), and the Working Group on Tree Nut Genetic Resources Identification, Evaluation and Conservation of the Inter-regional Cooperative Network on Nuts. Also within the context of ESCORENA, FAO supports the Plant Genetic Resources Conservation Sub-network of the Mediterranean Fruit Inter-country Network (MESFIN). MESFIN is collaborating closely with UFTANET and SEANUC in order to develop global-scale activities for the conservation of tropical fruit germplasm. A global network on citrus is being established through the merger of the ESCORENA Inter-Country Collaboration Network on Citrus Improvement for the Wider Mediterranean Region and the Inter-american Citrus Network (IACNET), both of which have sub-networks for the Citrus Germplasm Collection.

### 6.3.2 International Agricultural Research Centres

Most countries in their County Reports indicate some collaboration with the IARCs of CGIAR. CGIAR, established in 1971, is an informal association of public and private donors that supports the network of 16 IARCs, each of which has its own governing body.[60] As a donor-led group, it provides a forum for discussion of research priorities and coordinates the system's funding.

The United Nations Environment Programme (UNEP) has joined FAO, UNDP and the World Bank in co-sponsoring the system, and efforts are being made to increase the representation of developing countries.

In 1994, CGIAR decided to establish the System-wide Genetic Resources Programme (SGRP), with IPGRI as the convening centre. In addition to the components managed by the individual centres, the SGRP is responsible for high-priority collaborative activities such as the System-wide Information Network on Genetic Resources (SINGER) and public awareness and research activities on various system-wide issues. Research covers *in situ* and *ex situ* conservation and related activities, policy and socio-economic issues, information and training. Through the SINGER project, a standardized system of information management is being established to integrate databases throughout the CGIAR System and simplify communications with the national agricultural research systems (NARS). The SGRP encompasses activities on aquatic and livestock genetic resources as well as plant genetic resources including forestry. Representatives from the International Centres and FAO form an Inter-Centre Working Group on Genetic Resources (ICWG-GR) which acts as a steering committee for the System-wide Genetic Resources Programme. Through the SGRP, the IARCs make periodic reports to the Commission on Genetic Resources for Food and Agriculture.

The CGIAR's 12 commodity centres, each of which specializes in breeding one or more crop species of global significance (Table 6.2), have genetic resources units (or equivalent) which hold germplasm collections and which accept, in collaboration with NARS, responsibility for the conservation and adequate documentation of the entire gene pool, both domesticated and related wild species.[61] One CGIAR centre, IPGRI, is concerned solely with plant genetic resources management. It also promotes crop-specific networks for genetic resources management and takes a leading role in the conservation of many crops not covered by the other centres. The division of responsibility between IPGRI and FAO is laid out in a Memorandum of Understanding on Programme Cooperation, signed in 1990.

While the conservation of gene pools of mandate crops and their genetic enhancement is organized primarily on a global basis, other CGIAR activities, such as its natural resource management and farming systems' research, are organized on an ecoregional basis (Table 6.2). Increasingly, plant breeding also follows an ecoregional approach. IRRI, for example, has separate programmes for rice improvement in the lowlands and highlands.

As CGIAR centres take on additional ecoregional responsibilities, they need to determine, in consultation with national programmes, which species are likely to be of importance within a given ecoregion, and the extent to which a given centre is responsible for their conservation, evaluation and enhancement. During the preparatory process, many countries proposed that the research agenda of the IARCs be broadened to encompass a wider range of species.[62]

**Table 6.2 Mandate crops and ecoregional mandate of selected IARCs**

| Centre | Mandate crops | Ecoregional mandate |
|---|---|---|
| CIAT | Entire gene pool with global responsibility for field beans (*Phaseolus* spp.), cassava (in Africa IITA) and tropical forage crops for acid and infertile soils (in Africa with ILRI). Regional responsibility for rice in Latin America and the Caribbean (IRRI) | Emphasis on three agro-ecosystems in South America: savannahs with acid soils, hillsides with moderately acid, low-fertility soils (particularly at mid-altitudes) and cleared forest margins |
| CIP | Entire gene pool with global responsibility for potato, sweet potato and several minor Andean root and tuber crops | Originally focused on Andean region, but present mandate is global |
| ICARDA | Entire gene pool with global responsibility for barley, lentil, faba bean, durum wheat and "kabuli" chickpea, and regional responsibility for other wheats and pasture and forage crops | West Asia and North Africa (WANA region) |
| INIBAP (IPGRI) | Entire gene pool with global responsibility for banana and plantain (*Musa spp.)* | Global |
| ICRISAT | Entire gene pool with global responsibility for sorghum, "desi" chickpea, pigeon pea, groundnut, pearl millet, minor millet | Semi-arid tropics in South and Southeast Asia, sub-Saharan Africa (the Sahel belt, East and Southern Africa) and smaller areas in Latin America, North America, West Asia and Australia |
| IITA | Entire gene pool with global responsibility for cowpea and yam. Regional responsibility for cassava, maize, plantain, soybean, rice and agroforestry species | Humid forest zone of West and Central Africa; moist savannah zone (Guinea) and derived savannah of West Africa; mid-altitude and highland savannahs and woodlands of East and Southern Africa; inland valleys (together with WARDA) |
| IRRI | Entire gene pool with global responsibility for rice | Global, with a particular focus on Asia |
| WARDA | Rice | West Africa |
| ICRAF | Multipurpose trees of importance for agroforestry. No specific mandate species | Humid tropics (West Africa, South/Central America and SE Asia), sub-humid tropics (East African highlands, Southern African miombo zone); semi-arid tropics (Sudano-Sahelian zone of West Africa) |
| ILRI | No mandate crops. Pasture and forage species useful for livestock | Warm semi-arid, sub-humid, humid and cool tropical (highland) ecozones |
| CIFOR | Forestry species | Global |
| IPGRI | All crop species, particularly those of regional importance and non-mandate crops of other centres. Responsibility to advance conservation and use of plant genetic resources worldwide; special emphasis on developing countries | Global |
| IFPRI | International food policy issues | Global |
| ISNAR | Strengthen national agricultural research capabilities in developing countries | Global |

*Source*: Working Document AGR/TAC: IAR/92/94

As outlined, many IARCs provide leadership in regional and sub-regional networks, or are key participants in them. In addition to the crop-specific networks operating on a regional and sub-regional basis, there are a number of global networks. The following are co-ordinated by CGIAR centres:

- the Global Wheat Genetic Resources Network, co-ordinated by CIMMYT, which is developing a global database associated with the network which will distribute information to users;
- the International Wheat Nursery Cooperator Network, also co-ordinated by CIMMYT, which has been in existence for more than 30 years and works on a reciprocal basis for seed exchange;
- the IRRI rice network INGER;
- the Genetic Resource Information Package I network, also co-ordinated by CIMMYT, which collects information on pedigrees of released and named wheat cultivars worldwide; and
- the Global Cassava Genetic Resources Network, a sub-network of the Cassava Biotechnology Network, which is coordinated by CIAT.

IPGRI co-ordinates three crop networks which are involved in efforts to conserve, enhance and utilize genetic resources for their respective crop species: INIBAP is concerned with bananas and plantains; COGENT looks after coconut; and bamboo and rattan are under INBAR.

### 6.3.3 Other intergovernmental and international organizations

There are a number of other intergovernmental and international organizations which regularly provide reports to the Commission on Genetic Resources for Food and Agriculture.[63] These include:

- UNEP which carries out a wide range of activities related to plant genetic resources, many in collaboration with FAO and IPGRI. Currently, UNEP is focusing on the management of biodiversity in dryland areas. UNEP also provided the negotiating forum for the Convention on Biological Diversity and hosts its Secretariat;
- the United Nations Conference on Trade and Development (UNCTAD), through its Common Fund for Commodities, which works on expanding the utilization, production and trade of environmentally friendly products;
- the United Nations Industrial Development Organization (UNIDO) which has a biotechnology and biodiversity management programme;

- the Commonwealth Science Council (CSC), through its Biological Diversity and Genetic Resources Programme established in 1986, which supports member countries by providing training in plant genetic resources. CSC also supports networks to promote under-utilized species: UFTANET and SEANUC;
- the World Conservation Union (IUCN) which has many activities for plant genetic resources, particularly for *in situ* conservation.

The International Fund for Agricultural Development (IFAD) provides soft loans to countries for agricultural development projects aimed at alleviating rural poverty and improving nutrition. Utilization of plant genetic resources is a major component of many projects. IFAD now plays an important role in the implementation of the International Convention to Combat Desertification, and is placing greater emphasis on *in situ* conservation of plant genetic resources as part of an integrated approach to natural resource management. IFAD also issues technical assistance grants for international and national research relevant to reducing poverty. The World Bank plays a major role in strengthening NARS, while the Regional Development Banks finance development programmes, research and training.

The Global Environmental Facility (GEF), implemented by the World Bank, UNDP and UNEP, is a major fund for biodiversity management, and is the interim funding mechanism for the Convention on Biological Diversity. Two major projects on PGRFA are being funded through GEF, one for the conservation of crop wild relatives in Turkey, and the other for the conservation and development of crop landraces in Ethiopia. Other projects also have components relevant to PGRFA, particularly for forests and rangelands. However, only a small proportion of total GEF funding is directed towards PGRFA.

### 6.3.4 Bilateral programmes

In addition to their contributions to multilateral bodies and CGIAR, most major aid donors also finance activities on PGRFA conservation and use through bilateral projects and programmes in developing countries, some of which are noted in this chapter.

### 6.3.5 Programmes of private foundations and non-governmental organizations[64]

Private organizations such as the Rockefeller Foundation and The Ford Foundation were instrumental in establishing the first IARCs, and they continue as donors to the CGIAR. International non-governmental organizations play an increasingly important role in the conservation and utilization of PGRFA, and in carrying out associated advocacy and public education efforts. The World Wide Fund for Nature (WWF) is concerned with the *in situ* conservation of crop wild relatives and the sustainable management of wild food plants through programmes which promote the involvement of local people who use these resources.[65] The role of the IUCN, which includes NGOs, as well as countries in its membership, has already been mentioned.

The International Centre for Under-utilized Crops (ICUC) is playing a useful role in promoting conservation and utilization of under-utilized crops in different regions. Genetic Resources Action International (GRAIN) and Rural Advancement Foundation International (RAFI) have also played leading roles in promoting the debate concerning policy aspects of PGRFA conservation and use, mobilizing public opinion and working with regional and national NGO partners to develop alternative approaches, particularly with regard to on-farm management of PGRFA. NGO investment in this work is further explored in Chapter Two. The Keystone International Dialogue series on plant genetic resources has also provided an important forum for policy discussions.

## 6.4 INTERNATIONAL AGREEMENTS

### 6.4.1 The FAO International Undertaking on Plant Genetic Resources

The International Undertaking on Plant Genetic Resources is a non-legally binding instrument, adopted by the FAO Conference in 1983.[66] It is the only such instrument specifically devoted to PGRFA.

The Undertaking contains provisions for the exploration and collection of genetic resources (Article 3), for conservation *in situ* and *ex situ* (Article 4), for the availability of plant genetic resources (Article 5), for international cooperation in conservation, exchange and plant breeding (Article 6), for international co-ordination of genebank collections and information systems (Article 7) and for funding (Article 8).

Three complementary resolutions were unanimously adopted and are now annexes to the Undertaking. The first such resolution[67] provided an agreed interpretation of the Undertaking which recognized that plant breeders' rights were not inconsistent with the Undertaking.[68] It also recognized the concept of Farmers' Rights which was defined in a second resolution.[69] A third resolution[70] reaffirmed the sovereign rights of nations over their genetic resources and provided agreement that Farmers' Rights would be implemented through an international fund.

In November 1993, the Twenty-seventh Session of the FAO Conference unanimously adopted Resolution 7/93, which had been negotiated by the Fifth Session of the Commission, calling for the revision of the Undertaking, in harmony with the Convention on Biological Diversity.

The Resolution requests that the revision of the Undertaking be negotiated by countries, through regular and extraordinary sessions of the Commission with the assistance of its Working Group. This revision, which is currently under way, includes the negotiation of solutions to outstanding matters, such as access to plant genetic resources for food and agriculture, and the realization of Farmers' Rights.

## 6.4.2 The Convention on Biological Diversity

The Convention on Biological Diversity provides the main legal framework covering plant genetic resources and other components of biological diversity. The objectives of the Convention are the conservation of biological diversity, the sustainable utilization of its components, and the fair and equitable sharing of benefits derived from the utilization of genetic resources. These objectives are to be realized by appropriate access to genetic resources and the appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies, and appropriate funding. The Convention is comprehensive in scope, covering both *ex situ* and *in situ* conservation, and the sustainable use of biodiversity.

Most countries have ratified the Convention and are represented in the Conference of the Parties (CoP/CBD), which governs the implementation of the Convention, and in the Subsidiary Body on Scientific, Technical and Technological Advice. A major means of implementing the Convention is through national strategies which contracting parties are required to develop, and for these strategies to then be integrated into the relevant national programmes and policies. The Convention also provides for a clearing-house mechanism to promote and facilitate technical and scientific collaboration.

The CoP/CBD has established a working group to develop a draft protocol on biosafety.[71] With regard to PGRFA, the CBD has declared its support for the revision of the International Undertaking (see Section 6.5).

## 6.4.3 Other international agreements

Other agreements of relevance to PGRFA include (see also Chapter Five):

- the International Plant Protection Convention (IPPC) and a number of regional plant protection conventions which are concerned with phytosanitary measures. The IPPC is currently being revised to bring it into line with the agreement on phytosanitary measures of the World Trade Organization (WTO);
- the International Union for the Protection of New Varieties of Plants (UPOV) which is concerned with the promotion and protection of plant breeders' rights; and
- the WTO which includes an agreement on phytosanitary measures, as mentioned above, and an agreement on trade-related aspects of intellectual property rights (TRIPs) which requires members to adopt patents or a *sui generis* mechanism for the protection of plant varieties.

## 6.5 THE GLOBAL SYSTEM FOR THE CONSERVATION AND UTILIZATION OF PGRFA

Since 1983, upon the recommendations of its member countries, FAO has been developing a comprehensive Global System on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture. The objectives of the Global System are to promote the availability and sustainable utilization of plant genetic resources while ensuring their safe conservation for present and future generations, by providing a flexible framework for sharing the benefits and burdens. The Global System comprises a number of international agreements mechanisms and instruments. The present status of the Global System is summarized in Table 6.3.

The main institutional components of the Global System are the Commission on Genetic Resources for Food and Agriculture (Box 6.3) and the International Undertaking on Plant Genetic Resources (see section 6.5.1). The Commission's scope was broadened in 1995 to encompass all genetic resources for food and agriculture.

UNCED in its Agenda 21 requested that the Global System be strengthened, and the Commission has agreed that 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, would be a major contribution to 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.

The Conference of the Parties to the Convention on Biological Diversity has recognized the special nature of agricultural biodiversity, its distinctive features and problems requiring specially-tailored solutions, and has declared its support for the process under way in the FAO Commission on Genetic Resources for Food and Agriculture for the revision of the International Undertaking and for the process which culminated in Leipzig with the adoption of the Global Plan of Action.[72]

**Table 6.3 Status of the Global System on the Conservation and Utilization of PGRFA**

| Component(s) | Function | Status |
|---|---|---|
| Commission on Genetic Resources for Food and Agriculture | Intergovernmental global forum | Established 1983 as the Commission on Plant Genetic Resources; 146 countries and the EC are members; 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; 111 countries adhere; annexes agreed in 1989 (including Farmers' Rights) and 1991. Currently under revision including for harmonization with the CBD, development of agreements on access, and the realization of Farmers' Rights |
| International Fund for Plant Genetic Resources | To provide a channel for support and promotion of sustainable PGRFA conservation and use at a world level. | Not yet operational. Principle agreed by FAO Conference; Global Plan of Action (GPA) will be useful in determining requirements for Fund |
| Global Plan of Action for the Conservation and Sustainable Utilization of PGRFA | To rationalize and improve the international efforts for the conservation and use of PGRFA | Adopted by International Technical Conference (ITC), in June 1996 |
| Report on the State of the World's PGRFA | To report on all aspects of conservation and use of PGRFA to identify gaps, constraints and emergencies | First Report welcomed by International Technical Conference in June 1996 |
| World Information and Early Warning System (WIEWS) | To collect and disseminate data on PGRFA and related technologies; identifying hazards to genetic diversity | Information system established, including records of *ex situ* collections in 135 countries. Early Warning System at planning stage |
| Network of *ex situ* collections under the auspices of FAO | To facilitate access to *ex situ* collections on fair and equitable terms | Established with collections of 12 IARCs (agreement signed in October 1994); 32 countries expressed their willingness to include their collections; one has signed agreement. International standards agreed |
| Network of *in situ* areas | To promote conservation of landraces, crop wild relatives and forest genetic resources | No significant progress |
| International Code of Conduct for Plant Germplasm Collection and Transfer | To promote conservation including collection and use of PGRFA in ways that respect environment and local traditions and culture | Adopted by FAO Conference in 1993 |

> *(continued)* **Table 6.3 Status of the Global System on the Conservation and Utilization of PGRFA**

| Component(s) | Function | Status |
|---|---|---|
| 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 interregional or international networks established |

The number of countries and regional economic integration organizations that participate actively in the Global System is172

*Source*: Updated from FAO Programme Evaluation Report 1993-1994

**Box 6.3 Terms of Reference of the Commission on Genetic Resources for Food and Agriculture**[73]

The Commission shall have a coordinating role and shall deal with policy, sectorial and cross-sectorial matters related to the conservation and sustainable use of genetic resources of relevance to food and agriculture. Its terms of reference shall be:

- to keep under continuous review all matters relating to the policy, programmes and activities of FAO in the area of genetic resources of relevance to food and agriculture, including their conservation and sustainable use and the fair and equitable sharing of benefits derived from their utilization, and to advise the Director-General and the Council and, as appropriate, its technical committees, including in particular the Committees on Agriculture, Forestry and Fisheries, on such matters;
- to recommend such measures as may be necessary or desirable to ensure the development, as appropriate, of a comprehensive global system or systems on genetic resources of relevance to food and agriculture and to monitor the operation of its/their components, in harmony, where applicable, with the Convention on Biological Diversity and other relevant international instruments;
- to provide an intergovernmental forum for negotiations and to oversee the development, upon the request of the FAO Governing Bodies, of other international agreements, undertakings, codes of conduct or other instruments relating to genetic resources of relevance to food and agriculture, and to monitor the operation of such instruments;
- to facilitate and oversee co-operation between FAO and other international governmental and non-governmental bodies dealing with the conservation and sustainable use of genetic resources, in particular with the Conference of Parties to the Convention on Biological Diversity and the UN Commission on Sustainable Development, and to seek to develop appropriate mechanisms for cooperation and co-ordination in consultation with such bodies;
- subject to approval by the Governing Bodies of FAO, as appropriate, to respond to requests from the Conference of the Parties to the Convention on Biological Diversity in the specific area of genetic resources of relevance to food and agriculture, including the provision of information and other services to the Conference of the Parties and its subsidiary bodies, especially in the areas of early warning systems, global assessment and clearing-house facilities, in particular, and as appropriate, through the Global System on the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture.

### 6.5.1 International Network of *Ex Situ* Collections

The International Undertaking calls for the development of an international network of collections in genebanks under the auspices of FAO. Accordingly, an International Network of *Ex Situ* Collections has been established by the Commission on Plant Genetic Resources within the context of the Global System.[74] The Commission called for the development of this network in 1989, because of the uncertainty at that time, of the legal situation of germplasm collected in genebanks, and because of the lack of appropriate agreements to ensure its safe conservation.

The provisions in the Convention on Biological Diversity (Article 15) regarding access to genetic resources do not apply to collections assembled prior to its entry into force on 29 December 1993. The final document of the Nairobi Conference for the Approval of an Agreed Text for the Convention on Biological Diversity, in May 1992, recognized the need to resolve this issue, within the context of the Global System.

In 1994, the International Agricultural Research Centres of CGIAR signed agreements with FAO placing most of their collections, equivalent to about 7% of the world's collections, in the International Network (Table 6.4). Thirty-two countries also expressed their willingness to join the network,[75] and to date one, Morocco, has signed the agreement. At the sub-regional preparatory meeting for West and Central Africa, it was recommended that the countries of the region participate in the Network.[76]

During the preparatory process for the International Technical Conference, it was recommended that the institutions which signed agreements with IPGRI making commitments for the unrestricted availability and long-term conservation of their collections in the former IBPGR Register of Base Collections, now place those collections under the auspices of FAO in the International Network of *Ex Situ* Collections.[77]

The IBPGR Register comprises approximately 200,000 accessions collected with IBPGR support, as well as many much larger crop germplasm collections held by a long list of institutions. These collections are indicated in Appendix 2. Excluding CGIAR collections, they amount to about 16% of the world's accessions.[78] Thus, if these collections were to be brought into the International Network, access to about 23% of the world's collections (and undoubtedly a much higher proportion of the world's unique accessions) could be assured (Table 6.4).

## Table 6.4 The International Network of Ex *Situ* Collections

| Centre | Designated number of accessions | % of total germplasm collection | Notes |
|---|---|---|---|
| CIAT | 47,828 | 67 | |
| CIMMYT | 46,144 | 34 | |
| CIP | 11,846 | 85 | |
| ICARDA | 105,384 | 97 | |
| INIBAP (part of IPGRI) | 1,051 | 100 | |
| ICRISAT | 99,424 | 90 | |
| IITA | 36,378 | 92 | |
| IRRI | 79,277 | 98 | |
| ILRI | 10,587 | 79 | |
| ICRAF | | | Obligations of agreement not appropriate for collections of multipurpose trees. Designation pending review of obligations |
| WARDA | 4,872 | 28 | Most of the collection is duplicated at IRRI and/or IITA |
| **Total CGIAR** | **442,792** | **75** | |
| IBPGR Register | 973,607* | | **Not yet formally part of the network |
| Other collections of countries which have expressed willingness to join the network | 777,385* | | To date, only Morocco is formally part of the network |

Notes: *estimate; **see text

*Source*: SGRP[79] Review of the CGIAR Genebank Operations,1996, and WIEWS database

While the legal status of the relevant agreements is not always clear (as many were signed by IBPGR and the technical institution concerned, rather than with a governmental authority), the countries which host most of the institutions concerned were represented at the meetings where these recommendations were made.

The further development of the International Network was called for during the preparatory process.[80] It was proposed that the international network:[81]

- help countries share the burden of conservation;
- facilitate access to plant genetic resources;
- facilitate the sharing of benefits derived from their utilization.

The need for international funding, through the Global Plan of Action, to enable countries to meet the conditions needed for the conservation of designated germplasm, (i.e. adequate storage conditions, safety duplication and good documentation), was identified. In addition, it was suggested that, where necessary, legal agreements be developed to protect the rights of sovereign nations over national collections located in international, regional or sub-regional genebanks outside their territories.

A mechanism to facilitate access to and repatriation of accessions collected in developing countries but held in genebanks in other countries is also needed.[82] Further, it was emphasized that the Commission on Genetic Resources for Food and Agriculture has an important role to play in representing the interests of different countries participating in the international network.[83]

### 6.5.2 International Code of Conduct for Plant Germplasm Collecting and Transfer

The International Code of Conduct for Plant Germplasm Collecting and Transfer provides a framework which governments may use in developing national regulations or formulating bilateral agreements for the collection of germplasm. Many countries have used the Code in this way. The Code provides guidelines for the requesting of permits by collectors and for the issuance of such permits by state authorities, and it sets out minimum responsibilities of collectors, sponsors, curators and users of collected germplasm, covering both the collecting and transfer of germplasm. The Code was adopted by the Commission on Plant Genetic Resources and the 1993 FAO Conference as a voluntary instrument pending revision of the Undertaking.

It was agreed that the Code should be adapted to changing needs and circumstances, and updated or amended when appropriate through the Commission. During the preparatory process for the International Technical Conference, it was suggested that the International Code of Conduct for germplasm collecting and transfer be promoted.[84]

### 6.5.3 Draft Code of Conduct on Biotechnology

New plant biotechnology offer enormous possibilities for a more extensive use of the world's plant genetic resources.[85] However, the rapid advance of plant biotechnological research also raises uncertainties and, possibly, risks that require careful analysis.

The need for an international agreement on biosafety and bioethics which enables developing countries to evaluate the risks and control the importation of genetically modified organisms was identified in several preparatory meetings for the International Technical Conference.[86]

In 1991, the Commission requested FAO to draft a Code of Conduct on Biotechnology. Submitted to the Commission in 1993, a draft code aimed to maximize the positive effects and minimize the possible negative effects of biotechnology on the conservation and use of plant genetic resources. It included provisions dealing with the promotion of appropriate biotechnologies; national action and international cooperation; the prevention and mitigation of possible negative effects of biotechnology; access to plant genetic resources and related biotechnologies; intellectual property rights; compensation for informal innovators; and an information exchange and early warning mechanisms. Following the recommendation of the Commission at its Sixth Session, the components of the draft code concerning biosafety have been submitted to the Conference of the Parties to the Convention on Biological Diversity, as an input to the possible development of a protocol on biosafety. Further consideration of the proposed code has been deferred until after the revision of the International Undertaking.

### 6.5.4 The World Information and Early Warning System on Plant Genetic Resources (WIEWS)[87]

Following the recommendations of the Commission on Genetic Resources for Food and Agriculture, and with its guidance, FAO is developing a World Information and Early Warning System on PGRFA (WIEWS). The WIEWS collects, disseminates and facilitates the exchange of data and information on plant genetic resources and related technologies. It is also intended to alert the international community to hazards threatening the loss of *ex situ* and *in situ* plant genetic resources for food and agriculture, so as to make remedial action possible. The CGIAR-SPGR is setting up an integrated documentation system for the IARCs through the SINGER project.

### World information system on PGRFA

Most data in the WIEWS are provided by countries through replies to questionnaires.[88] The data are then stored in various databases and made available upon request. The data are intended to be used for the periodic updating of the Report on the State of the World's Plant Genetic Resources. Equally, information gained from Country Reports during the ITCPGR preparatory process during the preparation of these Reports is also stored in the WIEWS. Significant information was drawn from the WIEWS in preparing this document, for instance.

A number of databases and associated information retrieval systems are being developed:

- **Country Profiles Database** contains information on the structure of national plant genetic resources programmes and activities in 190 countries,[89] as well as the amount and type of germplasm held in genebanks or other collections.
- ***Ex Situ* Collections Database** contains summary records on over 4.5 million germplasm accessions held in some 1,220 *ex situ* collections in 135 countries.
- **Database of Databases** of national and international information systems on PGRFA does not duplicate information contained in any of the databases it lists, but provides profiles of the individual databases and a guide on how to obtain information from them.
- **Seed Sources Database** contains addresses and data on the activities and crop coverages of about 8,000 seed-supplying institutions around the world.
- **Crop Variety Database** contains information on commercial crop varieties. The database is made up of 55 crop files, with as many as 5,000 records in each.
- **Country Reports Database** contains summarized information from the Country Reports, prepared as part of the preparatory process for the Technical Conference, other than that included in the other databases above.

As requested by the Commission, efforts are being made to integrate these databases and improve their accessibility to potential users, electronically as well as through conventional means. Currently, data files are provided via electronic mail, on diskette, and as printouts and reports on paper in response to the several hundred requests for information which are received annually from inter-governmental, governmental and non-governmental institutions, as well as individuals.

The Commission on Genetic Resources for Food and Agriculture has proposed that WIEWS contribute to the clearing house mechanism of the Convention on Biological Diversity on matters related to plant genetic resources for food and agriculture,[90] and this idea has been welcomed by the Conference of the Parties.[91]

### Early warning mechanism

The need for an integrated early warning system or mechanism to monitor and respond to genetic erosion of PGRFA (both *in situ* and *ex situ*), as well as genetic uniformity and genetic vulnerability, is widely recognized.[92] Such a mechanism should draw upon both traditional knowledge and modern science. Similarly, mechanisms for rapid reaction and mobilization of resources are needed to avert the adverse consequences to plant genetic resources caused by drought, war and other catastrophes and emergencies.[93]

FAO is developing an Early Warning Mechanism as part of the WIEWS. It is not yet operational. Potential methodologies and strategies are being considered. Predictable and unpredictable emergency situations need different treatment. Similarly, approaches to material stored in *ex situ* and *in situ* conditions are also different.[94] The need to establish national level mechanisms for implementing any early warning mechanism is also recognized.[95]

## 6.6 ASSESSMENT OF MAJOR NEEDS TO IMPROVE INTERNATIONAL COLLABORATION

Article 7 of the International Undertaking on Plant Genetic Resources provides for the development of a Global System on Plant Genetic Resources, encompassing the work of FAO, other UN organizations and the IARCs as well as the international activities of regional and national institutions. One of the key objectives of the Global Plan of Action, as laid down by UNCED in Agenda 21, and set out in Resolution 3 of the Nairobi Final Act, is to strengthen the Global System and make it fully operational.

In recent years, the CGIAR system has become increasingly integrated with the FAO Global System as is evidenced, for example, by the designation of germplasm held by the IARCs to the International Network, the formation of the SGRP and its regular reporting to the Commission on Plant Genetic Resources for Food and Agriculture, and recognition by the CGIAR of the policy role of the intergovernmental Commission. Further integration, however, may be warranted. Co-operation with the informal sector of farmers, farmers' organizations and NGOs should also be facilitated.

A number of measures to strengthen the Global System were identified during the preparatory process for the International Technical Conference. An outline of these follows.

### Regional and sub-regional networks

In order to facilitate greater co-operation among the regional and sub-regional networks, it is necessary to strengthen the existing networks and integrate countries not presently part of them, and establish new networks in the following sub-regions: the Pacific, the Caribbean, the Indian Ocean Islands, the Central Asian states of the former Soviet Union, East Africa and West and Central Africa, and the Black Sea or Caucasus.[96] There is also a need to further strengthen the linkages between regional and sub-regional networks and the Global System, through the Commission on Genetic Resources for Food and Agriculture, in order to ensure co-ordination and effective policy-making at all levels.[97]

### Crop-specific networks

There is a need to develop crop-specific networks and strengthen linkages with the Global System through the Commission on Genetic Resources for Food and Agriculture. Global crop-specific networks could, for example, advise the Commission on the status of genetic diversity of the respective crops (see Chapter Four).[98]

### Information and Early Warning Systems

There is also a need to develop further the World Information and Early Warning System in order to make information more widely available. This should build upon existing systems and take into account national, regional and international differences and interests.[99] SINGER and WIEWS should be compatible, for example. There is also a need to develop the Early Warning Mechanism and to put it into practical operation.[100]

### International Network of Genebanks

There is a need for the further development of the International Network of Genebanks under the auspices of FAO in order to:

- include the IBPGR-designated base collections and other major collections assembled with international support;[101]
- provide options for the cost-effective storage of national collections, perhaps on a regional or sub-regional basis, backed up by firm legal agreements and by funding.[102]

Countries have also emphasized the importance of resolving the issues of access to and sharing of the benefits of genetic resources, including the realization of Farmers' Rights, within the context of the Global System. These issues are currently being considered by the Commission on Genetic Resources for Food and Agriculture, as part of the negotiations for the revision of the International Undertaking on Plant Genetic Resources.[103]

## Chapter 6 endnotes

[1] Agenda 21, Chapter 14G: Conservation and sustainable utilization of plant genetic resources for food and agriculture.

[2] Subregional preparatory meeting: North America Report, para 3; Subregional preparatory meeting: Europe Report, para 20; see also Chapter 1.

[3] Subregional preparatory meeting: West and Central Africa Report, para 27; Subregional preparatory meeting: East Asia Report, para 16; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, para 29, recommendation 17; Subregional preparatory meeting: South America Report, strategy (ii).

[4] Public goods have the following characteristics. They are non-rival in consumption terms (i.e. consumption of the good by one individual does not preclude consumption by others) and they are non-exclusive (i.e. having provided the good it is impossible, or excessively costly, to operate any mechanism to exclude others). Therefore, national and international management of public goods, including through regulation of exploitation, is generally necessary, to prevent misuse or overuse. Turner RK (ed.) 1993. *Sustainable environmental economics and management*. Belhaven Press, London.

[5] Subregional preparatory meeting: West and Central Africa Report, para 27.

[6] Ibid.; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii); Subregional preparatory meeting: East Asia Report, para 18.

[7] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii); Subregional preparatory meeting: West and Central Africa Report, para 33; Subregional preparatory meeting: Southern Africa Report, recommendation (ii).

[8] Subregional preparatory meeting: Central and West Asia Report, para 33; Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, general conclusions 12, 13.

[9] Subregional preparatory meeting: Central and West Asia Report, para 33.

[10] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii); Subregional preparatory meeting: Central and West Asia Report, para 33; Subregional preparatory meeting: Southern Africa Report, recommendation (ii).

[11] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii); Subregional preparatory meeting: Southern Africa Report, recommendation (ii); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, proposed area of activity 14.

[12] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, general conclusion 13.

[13] Subregional preparatory meeting: Central and West Asia Report, para 33.

[14] Subregional preparatory meeting: Mediterranean Report, para 25; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (vii).

[15] Subregional preparatory meeting: West and Central Africa Report, para 32.

16 Subregional preparatory meeting: Southern Africa Report, recommendation (v); Subregional preparatory meeting: North America Report, recommendation 16.

17 Subregional preparatory meeting: Europe Report, para 34(a).

18 Country Reports Czech Republic, Slovakia.

19 Country Reports Portugal, Spain.

20 Country Report Slovakia.

21 Country Report Spain.

22 Subregional preparatory meeting: Mediterranean Report, para 21. Among common problems, the importance of work relevant to arid and semi-arid areas was identified.

23 Subregional preparatory meeting: Mediterranean Report, para 22.

24 Subregional preparatory meeting: Mediterranean Report, para 20.

25 Subregional preparatory meeting: Central and West Asia Report, para 39.

26 South Africa is not yet fully integrated into SPGRC and has not yet established an NPGRC. During the preparatory process for the International Technical Conference, Mauritius became the twelfth member of SADC; however, it is not yet integrated into the SPGRC and for the purposes of the International Technical Conference and this document, Mauritius is included in the Indian Ocean Islands subregion.

27 Subregional preparatory meeting: Southern Africa Report, recommendation (iv).

28 Subregional Synthesis Report: East Africa, para 52.

29 Subregional preparatory meeting: West and Central Africa Report, para 27. Existing organizations include:

- political and economic intergovernmental bodies such as the Economic Community of West African States (ECOWAS) and the Economic Community of Central African States (ECCAS);
- technical intergovernmental bodies such as the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) for the Sahelian countries;
- the IARCs located in the region, including ICRISAT, IITA and WARDA;
- the network for coordination of agricultural research in West and Central Africa (CORAF);
- the Conference of Ministers of Agriculture of West and Central Africa.

30 Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, recommendation (6).

31 Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, para 29; proposed areas of activity 8 and 13.

32 Report of the Consultation Meeting on Plant Genetic Resources in the Eastern Caribbean States, Saint Lucia, 10-11 August 1995.

33 FAO Project GCP/RLA/108/ITA.

34 Subregional preparatory meeting: Mediterranean Report, para 24; Subregional preparatory meeting: West and Central Africa Report, para 33; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14 (vii).

35 Subregional preparatory meeting: Mediterranean Report, para 19; Subregional preparatory meeting: Central and West Asia Report, para 35; Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 6(e).

36 Subregional preparatory meeting: West and Central Africa Report, para 37; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xiii); Subregional preparatory meeting: North America Report, para 2(h).

37 Subregional preparatory meeting: Central and West Asia Report, para 14.

38 Subregional preparatory meeting: West and Central Africa Report, para 34; Subregional preparatory meeting: Mediterranean Report, para 23.

39 Subregional preparatory meeting: West and Central Africa Report, para 35; Subregional preparatory meeting: Southern Africa Report, recommendation (iii).

40 Subregional preparatory meeting: Central and West Asia Report, para 35.

41 FAO (1995) *Recent international developments of relevance to the draft Code of Conduct for Plant Biotechnology*. Paper for the Commission on Plant Genetic Resources, Sixth Session. CPGR-6/95/15.

42 Cohen JI and Komen J (1994) International agricultural biotechnology programmes: Providing opportunities for national participation, *AgBiotech News and Information*, 6:257-267.

43 These programmes involve funding organizations, such as UNDP, the Rockefeller Foundation, the McKnight Foundation, the United States Agency for International Development (USAID) and the Netherlands' Directorate General for International Cooperation (DGIS); crop research networks and programmes, including FAO, REDBIO's International Programme on Rice Biotechnology, the Asian Rice Biotechnology Network, the Cassava Biotechnology Network and the Asia Network for Small-scale Agricultural Biotechnologies (ANSAB); international and regional research institutes, including the CGIAR Centres, the International Centre for Genetic Engineering and Biotechnology (ICGEB), the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), the International Laboratory for Tropical Agricultural Biotechnology (ILTAB), the Agricultural Biotechnology for Sustainable Productivity project (ABSP), the United Kingdom Overseas Development Administration (ODA) Plant Sciences Research Programme and the African Biosciences Sub-Network for Biotechnology (ABN-BIOTECHNET); broker organizations, such as the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and programmes concentrating on policy and management issues, run by organizations such as the Inter-American Institute for Cooperation on Agriculture (IICA), the Intermediary Biotechnology Service (IBS), the African Centre for Technological Studies (ACTS), Research and Information Centre for the Non-aligned and other Developing Countries (RIS) and the Rural Advancement Foundation International (RAFI).

44 Altman DW (1993) Plant biotechnology transfer to developing countries. *Current Opinion in Biotechnology*, 4:177-179.

45 This approach is presented in Scoones I and Thompson J (eds.) (1994) *Beyond farmer first: rural peoples' knowledge, agricultural research and extension practice*. Intermediate Technology Publications, London; and in De Boef W, Amanor K, Wellard K and Bebbington A (eds.) (1993) *Cultivating knowledge: genetic iversity, farmer experimentation and crop research*. Intermediate Technology, London.

46 FAO (1995) *Reports, programmes and activities on plant genetic resources: 1*. Report on FAO's Activities CPGR-6/95/5.1, para 38.

47 About 1,400 million people are dependent on resource-poor farming systems; Chambers R (1994) in Scoones I and Thompson J (eds.) *Beyond farmer first: rural people's knowledge, agricultural research and extension practice*, p. xiii. Intermediate Technology Publications, London.

48 Dhar B and Pandey B (1994) Biovillages in India: An attempt to diffuse biotechnology in rural areas. *Biotechnology and Development Monitor*, 18:16-17. In the Netherlands, the Information Centre for Low-External-Input and Sustainable Agriculture (ILEIA) and the Centre for International Research and Advisory Networks (CIRAN) promote low external-input, sustainable agricultural systems, and the use of indigenous knowledge in relation to agricultural development, respectively.

49 Altman DW (1994) Technology transfer initiatives of the International Service for the Acquisition of Agri-biotech Applications. *AgBiotech News and Information*, 6:131-134; Knudsen H (1993) ISAAA: Proprietary technology for small farmers. *Biotechnology and Development Monitor*, 14:12-13.

50 Komen J (1993) The Intermediary Biotechnology Service. *Biotechnology and Development Monitor*, 17:18-19; The Intermediary Biotechnology Service (IBS) was established at the International Service for National Agricultural Research (ISNAR) by an international group of donor agencies, to act as an independent advisory service on issues of biotechnology research management, information exchange, institution building, policy formulation and the assessment of the socio-economic impact of biotechnologies. IBS has a collaborative project with Giessen University (Germany) and the Federal Institute of Technology (Switzerland) to assess the potential socio-economic impact of new plant biotechnologies on cocoa production and competitiveness.

51 Brenner C and Komen J (1994) *International initiatives in biotechnology for developing countries agriculture: promises and problems*. Technical Paper No. 100, OECD Development Centre.

52 Sasson A and Costarini V (eds.) (1991) *Biotechnologies in perspective*, UNESCO: Paris.

53 Galhardi R (1993) *Employment and income effects of biotechnology in Latin America: a speculative assessment*. International Labour Office, Geneva; Ahmed I (ed.) (1992) *Biotechnology: A hope or a threat?* Macmillan, London.

54 Pistorius R (1993) RAFI after 15 years. *Biotechnology and Development Monitor*, 17:22.

55 Van Roozendaal G (1993) The International Program on Rice Biotechnology. *Biotechnology and Development Monitor*, 15:20-21.

56 Thro AM, Henry G and Lynam JK (1994) Biotechnology and small-scale farmers. *Biotechnology and Development Monitor*, 21:8-19.

57 Reported by IBS to be: Kenya, Zimbabwe and Egypt in Africa; Indonesia, Thailand and India in Asia; and Costa Rica, Mexico and Brazil in Latin America.

58 Op. cit., endnote 51.

59 Op. cit., endnote 46.

60 Ôzgediz (1993) Organization and management of the CGIAR system: a review. *Public Administration and Development* 13:217-231.

61 Based on TAC (1992*) Changing responsibilities and roles for plant genetic resources within the CGIAR system*. TAC Working Document: AGR/TAC:IAR/92/24.

62 Subregional preparatory meeting: Southern Africa Report, para 12(xix).

63 FAO (1995) *Reports, programmes and activities on plant genetic resources: 1*. Reports of the activities of intergovernmental and international non-governmental organizations. This report also includes the activities of the IARCs, WTO, UPOV, and NGOs. CPGR-6/95/5.2.

64 FAO (1993) Reports on activities on plant genetic resources by FAO, IBPGR and other organizations. Paper for the Commission on Plant Genetic Resources, Fifth Session. CPGR/93/6.

65 Ibid.

66 FAO Conference Resolution 8/83.

67 FAO Conference Resolution 4/89.

68 A number of mostly developed countries were concerned that the demand for availability "without restriction", coupled with the wide definition of plant genetic resources in the Undertaking to include commercial varieties, might be incompatible with their legislation on plant breeders' rights.

69 FAO Conference Resolution 5/89.

70 FAO Conference Resolution 3/91.

71 Decision II/15 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indonesia, 6-17 November 1995.

72 Ibid.

73 FAO (1995) Report of the Council, 110th Session.

74 In accordance with Article 7 of the International Undertaking.

75 These are: Argentina, Bangladesh, Chile, Costa Rica, Czech Republic, Denmark, Ethiopia, Finland, France, Germany, Indonesia, India, Italy, Japan, Iraq, Madagascar, Morocco, the Netherlands, Norway, Pakistan, the Philippines, Russian Federation, Senegal, Spain, Sweden, Switzerland, Syrian Arab Republic, Togo, Tunisia, United Kingdom, Uruguay and Yemen. At the subregional preparatory meeting, it was also agreed that the countries of West and Central Africa should participate in the international network.

76 Subregional preparatory meeting: West and Central Africa Report, para 37.

77 Subregional preparatory meeting: North America Report, recommendation (h); Subregional preparatory meeting: Europe Report, recommendation 22(c).

78 This estimate assumes that for each institute that has a crop collection designated in the IBPGR register, the designation applies to the whole collection. Collections that contain less than 1% of the global total for that crop are not included in the estimate.

79 SGRP (1996) Report of the Internally Commissioned External Review of the CGIAR Genebank Operations, 1996. At the time that data for this table were assembled, CIMMYT, for example, was not sure whether the large number of accessions of breeding lines in the collection were appropriate for designation. This explains the seemingly low percentage of the collection designated by the Centre. Subsequently, these materials have been designated. Designation numbers and percentages are constantly changing as materials enter collections. The figures in this table were accurate at the time they were assembled for the footnote document.

80 Subregional preparatory meeting: Europe Report, recommendation 22(d); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xiii).

81 Subregional preparatory meeting: West and Central Africa Report, para 37.

82 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (xiii).

83 Subregional preparatory meeting: West and Central Africa Report, para 37.

84 Subregional preparatory meeting: Southern Africa Report, para 12(vi); Subregional preparatory meeting: East Africa and Indian Ocean Islands Report, para 14(xi).

85 Documents CPGR/89/9, CPGR/91/12 and CPGR/93/9 provide more extensive information and discussion of the potential of plant biotechnologies for international agriculture. See also: FAO (1993) *Biotechnologies in agriculture, forestry and fisheries.* Rome.

86 Subregional preparatory meeting: South America Report, programme proposal 1.5; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation (x).

87 WIEWS was established in conformity with Articles 7.1 (e) and (f) of the International Undertaking on Plant Genetic Resources, and with the recommendation of the Commission on Plant Genetic Resources that FAO develop an information system on plant genetic resources. Article 11 of the Undertaking provides for "Governments and institutions [...] to provide the Director-General of FAO with information on the measures that they have taken or propose to take to achieve the objectives of [the] Undertaking".

88 In particular, a questionnaire entitled "Survey of national plant genetic resources activities for agricultural species" jointly developed by FAO and IPGRI, was distributed by a Circular State Letter in May 1994 to both FAO member and non-member countries, with a request that they validate, correct or complete the data. As a follow-up to this distribution, copies of the questionnaire and appendix were distributed to national coordinators in the various countries, to facilitate a response. As a result, 56% of the questionnaires have been returned.

89 The WIEWS databases now contain data on 190 countries. This includes information on at least one institute and one contact point in the agriculture sector.

90 Commission on Plant Genetic Resources 6/95/REP, para 39.

91 Decision II/16 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indonesia, 6-17 November 1995.

92 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xv).

93 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xvi).

94 FAO (1995) Commission on Plant Genetic Resources 6/95/13, para 24.

95 FAO (1995) Commission on Plant Genetic Resources 6/95/REP, para 38.

96 Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 32 (6); Subregional preparatory meeting: Central America, Mexico and the Caribbean Report, area of activity 9; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(vii); Subregional preparatory meeting: Central and West Asia Report, para 33; Subregional preparatory meeting: West and Central Africa Report, para 27, and the Global Plan of Action, para 254.

[97] FAO (1995) Commission on Plant Genetic Resources 6/95/REP, para 46.

[98] Subregional preparatory meeting: Southern Africa Report, recommendation (v); Subregional preparatory meeting: North America Report, para 16(a).

[99] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xiv).

[100] Subregional preparatory meeting: South America Report, programme proposal 1.5; Subregional preparatory meeting: East Africa and the India Ocean Islands Report, recommendation (x); Subregional preparatory meeting: West and Central Africa Report, para 46.

[101] Subregional preparatory meeting: North America Report, para 2(h); Subregional preparatory meeting: Europe Report, para 22(d).

[102] Subregional preparatory meeting: Mediterranean Report, para 24; Subregional preparatory meeting: West and Central Africa Report, para 33; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(vii); Subregional preparatory meeting: Mediterranean Report, para 19; Subregional preparatory meeting: West and Central Africa Report, para 35; Subregional preparatory meeting: South, Southeast Asia and the Pacific Report, para 6(e); Subregional preparatory meeting: Central and West Asia Report, para 14; Subregional preparatory meeting: West and Central Africa Report, para 34; Subregional preparatory meeting: Mediterranean Report, para 14(xxiii); Subregional preparatory meeting: West and Central Africa Report, para 35; Subregional preparatory meeting: Southern Africa Report, recommendation (iii).

[103] All Subregional preparatory meetings.

# CHAPTER 7
# Access to Plant Genetic Resources, the Sharing of Benefits Derived from their Use and the Realization of Farmers' Rights

## 7.1 INTRODUCTION

The two related issues of access to genetic resources, and the fair and equitable sharing of the benefits derived from the use of genetic resources, have been widely discussed over the last decade, particularly by the FAO Conference and the Commission on Plant Genetic Resources Food and Agriculture.[1] More recently, these issues have been highlighted during the negotiations for the Convention on Biological Diversity and, following the entry into force of the Convention at the end of 1993, by the Conference of the Parties. These issues were also widely discussed during the preparatory process for the International Technical Conference.

These two issues are crucial to the conservation and sustainable utilization of plant genetic resources for food and agriculture (PGRFA). As noted in the previous Chapters, continued access is required to enable PGRFA to be utilized fully and for their cost-efficient conservation. The sharing of the benefits is not only a matter of justice and equity, but also one of providing the necessary incentives and means for the conservation and development of plant genetic resources by the countries, farmers and communities which hold them and, thereby, ensuring that the resources on which all depend are conserved and available in the future.

A number of the needs for the conservation and sustainable utilization of PGRFA, identified in earlier Chapters of this Book, are relevant to the accessibility and benefit-sharing of these resources, and are mentioned in this Chapter. These include activities required to allow developing countries and, in particular, their resource-poor farmers to benefit fully from the use of PGRFA. Relevant recommendations in response to these issues, made during the course of the preparatory process for the International Technical Conference, are referred to at the appropriate points.

This Chapter is organized into the following sections:

- a review of the legal and policy framework;
- a review of the state of access to genetic resources and the distribution of samples;
- a review of the benefits derived from PGRFA, including:
  - an assessment of the global benefits realized,
  - a review of the state of benefit-sharing between countries, including access to germplasm and improved varieties and other forms of technology transfer, scientific cooperation and capacity building,
  - a review of the state of benefit-sharing among farmers and communities;
- a review of current financing of PGRFA activities;
- further considerations regarding the implementation of Farmers' Rights;
- overall conclusions.

## 7.2 THE LEGAL AND POLICY FRAMEWORK

### The Convention on Biological Diversity

The Convention provides the general legal framework within which international mechanisms concerning access and the sharing of benefits are likely to operate in the future. It has been ratified by most countries. The fair and equitable sharing of benefits is one of the three objectives of the Convention on Biological Diversity, along with the promotion of conservation and sustainable utilization. Access to genetic resources, the related technologies and information and the necessary funding are the means to these objectives. The Convention recognizes the "sovereign rights of states over natural resources"[2] and acknowledges that states have the authority to determine access to genetic resources. The Convention requires that Contracting Parties create the conditions needed to facilitate access to these resources. Contracting Parties should also facilitate access to technologies, including biotechnology. Finally, the Convention includes provisions designed to channel benefits back to the countries that provide genetic resources, particularly developing countries (Box 7.1).

### Box 7.1 Access to genetic resources and the fair and equitable sharing of benefits derived from their use: provisions of the Convention on Biological Diversity

On the subject of access to genetic resources, the Convention reaffirms "the sovereign rights of states over their natural resources" and states that "the authority to determine access to genetic resources rests with the national governments and is subject to national legislation" (Art.15.1). However, the Convention elaborates on this basic point of departure in three important ways. First, it states that Parties "shall endeavour to create conditions to facilitate access to genetic resources" and "not to impose restrictions which run counter to the objectives of this Convention" (Art.15.2). Second, it strengthens the position of Parties to implement their sovereign rights to determine access by requiring that access "shall be subject to prior informed consent" of the country providing the resources, unless otherwise determined by that country (Art.15.5) and that "access, where granted, shall be on mutually agreed terms" (Art.15.4). Third, the Convention provides for the fair and equitable sharing of benefits derived from genetic resources with the country of origin, or the country providing such resources where they have been acquired in accordance with the Convention (Arts. 15.7, 16.3, 19.1, and 19.2).

The provision for benefit-sharing states: "Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, and in accordance with Articles 16 and 19 and where necessary through the financial mechanism established by Articles 20 and 21 with the aim of sharing in a fair and equitable way the results of research and development, and the benefits arising from the commercial and other utilization of genetic resources, with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms" (Art 15.7).

These benefits are to include:

- access to and transfer of technology which makes use of those genetic resources (Art 16.3). This should include technologies protected by intellectual property rights consistent with such rights, and states should also take action with the aim that the private sector facilitates access to and joint development of relevant technologies;
- participation in biotechnological research based upon such genetic resources (Art 19.1);
- priority access to the results and benefits arising from such biotechnological research (Art 19.2).

In addition, Article 17 requires Parties to facilitate the exchange of information, including results of research, while Article 18 calls upon parties to promote international technical and scientific collaboration, where necessary through appropriate international and national institutions. Special attention should be given to the development and strengthening of national capabilities through training and institution-building. A clearing-house mechanism will be established to facilitate these activities.

The Convention establishes that developed country Parties will provide new and additional financial resources to enable developing country parties to meet the "agreed full incremental costs" necessary for implementation of the Convention (Art. 20.2) and that a financial mechanism will operate within a "democratic and transparent system of governance" (Art. 21.1). The financial mechanism "shall function under the authority and guidance of, and be accountable to, the Conference of the Parties" (Art.21.1). The Global Environmental Facility (Para. 27) is the interim financial structure (Arts. 27 and 39). The Convention provides that countries should "encourage the equitable sharing of the benefits arising from the utilization of (...) the knowledge, innovations and practices; indigenous and local communities embodying traditional lifestyles relevant to the conservation and sustainable use of biological diversity" Article 8(j).

## Box 7.2 Farmers' Rights

At the FAO Conference in 1989, member countries endorsed the concept of Farmers' Rights in Resolution 5/89 which defined Farmers' Rights as *"rights arising from the past, present and future contributions of farmers in conserving, improving, and making available plant genetic resources, particularly those in the centres of origin/diversity."* This resolution became an integral part of the Undertaking as its second annex.

According to the resolution, *"these rights are vested in the International Community as trustees for present and future generations of farmers, for the purpose of ensuring full benefits to farmers, and supporting the continuation of their contributions, as well as the attainment of the overall purposes of the International Community, in order to:*

(a) ensure that the need for conservation is globally recognized and that sufficient funds for these purposes will be available;

(b) assist farmers and farming communities, in all regions of the world, but especially in the areas of origin/diversity of plant genetic resources, in the protection and conservation of their plant genetic resources, and of the natural biosphere;

*(c) "allow farmers, their communities, and countries in all regions, to participate fully in the benefits derived, at present and in the future, from the improved use of plant genetic resources, through plant breeding and other scientific methods."*

The resolution noted that: *"the majority of these plant genetic resources come from developing countries"* and that therefore there was a need to strengthen the capabilities of developing countries in the conservation, development and use of these resources. A global fund was envisaged for this purpose.

In response to the need for such a mechanism, a further resolution was agreed upon at the FAO Conference in 1991. This resolution (C 5/91), which became the third annex to the Undertaking, endorsed several points including: "that *Farmers' Rights will be implemented through an international fund on plant genetic resources which will support plant genetic conservation and utilization programmes, particularly, but not exclusively, in the developing countries."* It was further agreed that *"the resources for the international fund as well as for other funding mechanisms should be substantial, sustainable and based on the principles of equity and transparency. "* While this fund was not necessarily to be established within FAO, it was agreed that *"through the Commission on Plant Genetic Resources, the donors of genetic resources, funds and technology will determine and oversee the policies, programmes and priorities of the fund and other funding mechanisms, with the advice of the appropriate bodies."*

As yet, no agreement has been reached regarding the nature and size of contributions to the fund. The Commission on Plant Genetic Resources decided that the technical and financial requirements of ensuring the conservation and promoting the sustainable use of the world's plant genetic resources needed to be determined and quantified. The Commission agreed that this should be done through the development of a Report on the State of the World's Plant Genetic Resources and a costed Global Plan of Action, a decision subsequently endorsed by the UNCED. The financing of the Global Plan of Action would be a contribution to the realization of Farmers' Rights.

### Farmers' Rights and the International Undertaking on Plant Genetic Resources

The International Undertaking on Plant Genetic Resources, including its annexes,[3] promotes the availability of plant genetic resources for the purposes of scientific research, plant breeding and genetic resource conservation.[4] However, breeders' lines and farmers' breeding material are to be made available only at the discretion of their developers during the period of development.[5] The Undertaking recognizes that nations have sovereign rights over PGRFA.[6]

One of the stated purposes of Farmers' Rights is to "*allow farmers, their communities, and countries in all regions, to participate fully in the benefits derived, at present and in the future, from the improved use of plant genetic resources, through plant breeding and other scientific methods*"[7] (see Box 7.2).

This was the first time that the role of farmers in developing plant varieties had been recognized by an intergovernmental body. The preamble to the resolution considered that: *"in the history of mankind, unnumbered generations of farmers have conserved, improved and made available plant genetic resources"* and that *"the contribution of (...) farmers has not been sufficiently recognized or rewarded".* Subsequently this concept has been supported in other international fora, notably in UNCED's Agenda 21, which called upon FAO to promote the realization of Farmers' Rights.

The Convention on Biological Diversity does not specifically refer to Farmers' Rights. It also does not include provisions governing access to *ex situ* collections assembled prior to the Convention's entry into force. These issues are, therefore, being followed up in the context of the FAO Global System for the Conservation and Sustainable Use of Plant Genetic Resources, as agreed during the UNCED process.[8]

With the support of the Conference of the Parties to the Convention on Biological Diversity,[9] the International Undertaking is currently being revised in harmony with the Convention on Biological Diversity, through negotiations between countries in the Commission on Genetic Resources for Food and Agriculture. The negotiations include consideration of the issues of access, on mutually agreed terms, to plant genetic resources and the realization of Farmers' Rights.[10]

## 7.3 THE STATE OF ACCESS TO PLANT GENETIC RESOURCES

Traditionally, access to plant genetic resources for food and agriculture has been unrestricted. Free access to plant genetic resources, including improved varieties and other research products derived from plant genetic resources, as well as wild resources and farmers' varieties, was provided for in the original text of the International Undertaking on Plant Genetic Resources, adopted in 1983.[11] The Convention on Biological Diversity requires parties to promote and/or facilitate access to plant genetic resources on mutually agreed terms.

The fact that the agricultural systems of virtually all countries are highly dependent upon introduced crop species is testimony to the wide dispersal of materials throughout history, from the earliest days of agriculture.

### 7.3.1 Exchange of plant genetic resources from *in situ* conditions and *ex situ* collections

More than 1,300 genebanks hold over six million accessions, largely as a result of the wide degree of access to PGRFA historically. Many of these accessions are landraces collected from farmers' fields. Networking among *ex situ* collections facilitates the exchange of genetic resources. China, for example, has established germplasm exchange relations with more than 90 countries. China receives over 3,000 accessions annually from abroad, while a similar number are provided from Chinese genebanks to other countries. Over the last five years, the Canadian plant genetic resources centre has received from other countries about 7,000 samples per year, and sent out about 1,500 samples to 42 countries every year. Brazil's CENARGEN has received an average of 9,500 accessions annually, and provided about 2,200 per year to other countries. The national plant genetic resources system of the United States distributes about 40,000 accessions of germplasm to foreign scientists each year, while Germany provides about 9,000 samples per year to other countries.[12] For those countries which provided this information, germplasm sent abroad on average accounts for about 30% of all samples distributed by the countries' genebanks.[13]

The CGIAR plays an important role in germplasm exchange. Its 600,000 accessions may represent between 20% and 50% of unique material stored *ex situ*.[14] About half of the 122,000 germplasm samples distributed each year from the Centres' genebanks are used by the Centres themselves (Chapter Four, Table 4.1), while about 60,000 samples are distributed outside the respective Centres (Table 7.1). In general, developing country national agricultural research

**Table 7.1 Percentage of germplasm samples distributed annually by CGIAR centres, by sector (1992 -1994)**

| | Other international agricultural research centres | Developing country national agricultural research system | Developed country national agricultural research system | Private sector | Total number of samples distributed outside the centres |
|---|---|---|---|---|---|
| | % | % | % | % | No. |
| **CIAT** | | | | | |
| *Phaseolus* | 0 | 54 | 46 | 0 | 1,979 |
| Manihot | 0 | 59 | 40 | 1 | 422 |
| Forage legumes | 16 | 51 | 27 | 6 | 1,655 |
| **Total** | **7** | **53** | **37** | **3** | **4,056** |
| **CIMMYT** | | | | | |
| Maize | 0 | 20 | 72 | 8 | 2,234 |
| Wheat | 0 | 69 | 28 | 3 | 2,372 |
| **Total** | **0** | **45** | **49** | **6** | **4,606** |
| **WARDA** | | | | | |
| **Total** | **25** | **75** | **0** | **0** | **1,872** |
| **ICARDA** | | | | | |
| **Total** | **5** | **63** | **32** | **0** | **13,013** |
| **CIP*** | | | | | |
| Potato | - | 93 | 7 | - | 3,929 |
| Sweet potato | - | 95 | 5 | - | 1,023 |
| **Total** | **-** | **93** | **7** | **-** | **4,952** |
| **IITA** | | | | | |
| **Total** | **13** | **66** | **21** | **0** | **3,895** |
| **ICRISAT** | | | | | |
| **Total** | **0** | **91** | **2** | **7** | **19,570** |
| **IRRI** | | | | | |
| **Total** | **7** | **52** | **39** | **2** | **7,207** |
| **ILRI** | | | | | |
| **Total** | **9** | **64** | **7** | **20** | **1,071** |
| **INIBAP**** | | | | | |
| **Total** | **3** | **64** | **33** | **0** | **371** |
| **TOTAL** | **4** | **72** | **21** | **3** | **60,613** |

* Data not reported either for other IARCs or for private sector

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

*Source*: SGRP Review of the CGIAR Genebank Operations,1996

systems (NARS) are the main recipients of these released samples: 72% of the total number of samples distributed outside of the particular centres. For instance, 93% of germplasm samples of potato and sweet potato released by CIP, and 91% of ICRISAT's samples went to developing country NARS during the period 1992-94. However, the main recipient of maize samples from CIMMYT were developed country NARS (72%). The private sector, in general, is a minor beneficiary. The highest proportion of released germplasm samples to the private sector involve forage crops from ILRI and maize from CIMMYT.

The figures discussed above show that Canada and Brazil, for example, each receive four or five times as many samples as each country sends out, while the United States distributes more than it receives. But, according to records kept by the IARCs, virtually all countries have received more germplasm samples from the Centres than each has contributed.[15] The world's largest and most complete collection of rice, at IRRI, comprises more than 80,000 samples from 111 countries. The collection includes, for example, 8,454 samples from Indonesia, 7,999 samples from Sierra Leone, and 849 samples from Brazil.[16] These countries and all others have access to the entire collection. For any one country to have access to the same range of rice diversity through bilateral arrangements, it would be necessary to conclude agreements with 110 countries.[17] For all countries to have access to this material, about 20,000 separate bilateral agreements would be necessary.

### 7.3.2 Exchange of improved crop varieties

Most of the genetic resources exchanged internationally comprise enhanced germplasm and released cultivars. In addition to the 60,000 samples distributed from the Centres' genebanks, CGIAR centres make available some 500,000 samples of improved material to over 120 countries yearly. These include segregating populations, advanced breeding lines, finished varieties and specialized genetic stocks. Many crop improvement programmes, particularly in developing countries, depend heavily on these materials which they receive free of charge from the IARCs. Developed countries also benefit greatly from germplasm provided by the Centres.[18]

Data on the origin of rice varieties illustrate the heavy reliance on the exchange of improved germplasm.[19] A major study of 1,709 varieties released between 1965 and 1991 showed that a quarter were imported, the result of both breeding work and genetic resources originating outside the importing country. IRRI was the source of 17% of the total, while other national programmes were responsible for 6%. After IRRI, India was the next largest exporter of varieties, with 28 Indian varieties released elsewhere. India was also a large importer of varieties: 70 of its 643 varieties originated elsewhere, with 53 from IRRI. Sri Lankan varieties were released 11 times in other countries. Twelve Thai varieties were released in Myanmar. Myanmar was one of the largest importers of rice varieties: 43 of its 76 releases were imported varieties, including varieties from Bangladesh, China, India, Indonesia, IRRI, the Philippines, Sri Lanka, Thailand and Viet Nam.

Perhaps more remarkable than the direct international flow of varieties has been the international flow of parents of the rice varieties.[20] Nearly three-quarters of the released varieties have at least one imported parent. About half (47%) have at least one parent from IRRI, and a third (36%) have at least one parent from another national programme. The extent of international exchange, both of varieties and of parents, implies that a large majority of the varieties released were developed using breeding lines from outside the country of release. In fact, only 145 varieties out of 1,709 (8.5%) were developed entirely from own-country parents and other ancestors (Figure 7.1). Most of these were simple varieties with fewer than 4 ancestors in their pedigree. All countries examined in this study have taken advantage of unimproved or improved germplasm from other countries.

In addition to its direct role as a source of exported varieties, IRRI has served as a conduit through which elite lines have moved from country to country, especially after the establishment of the International Network for the Genetic Evaluation of Rice (INGER) in 1975.[21] Through INGER's activities, elite lines and released varieties from national research programmes have been made available for international testing and evaluation. During the same period, the number of national programme varieties imported through other avenues has diminished from 13, during the period from 1976 to 1980, to six during the period from 1986 to 1991. INGER has played an important role in facilitating the transfer of varieties across geographic zones; for instance, both of the Sri Lankan varieties released in Africa came through INGER, as did both of the Indian varieties released in Latin America.

**Sources of rice varieties released by national programmes, 1986-1991**

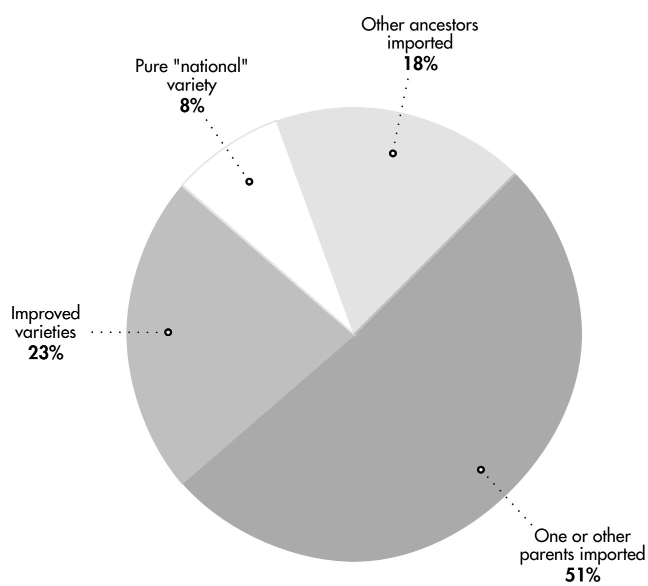



Figure 7.1 Source: Evenson and Gollin (1996); Gollin (1996)

## 7.3.3 Restrictions on access

There have always been some exceptions to the free exchange of genetic resources. In some cases, mostly where high-value export crops are concerned, countries appear to have restricted access to unique and potentially valuable undeveloped germplasm, as a matter of policy. Coffee, cotton, oil-palm, black pepper, pyrethrum, rubber and tea are examples of species for which the export of genetic material has been restricted by some countries. Occasionally, political disagreements between countries on matters unrelated to PGRFA have made access problematic. More frequently, the lack of resources for multiplication and processing have impeded availability, especially when there has been a large demand for a particular resource.[22] Although quarantine procedures may impose necessary delays on germplasm exchange, such procedures are generally designed to minimize risks of introducing pests and diseases along with the germplasm. Overall, the great majority of unique PGRFA accessions in *ex situ* collections has been generally available for plant breeding and research purposes.

Exceptions are breeders' lines and other material under development, which is available only at the discretion of the developers,[23] and some material protected by intellectual property rights (Box 7.3). During the preparatory process for the International Technical Conference, some countries expressed particular concern that the patenting of plants, genes and genetic characteristics might lead to new barriers in the availability of PGRFA.[24]

The Convention on Biological Diversity does not address the issue of intellectual property rights with respect to access to genetic resources themselves. However, it does require Contracting Parties "to create conditions to facilitate access to genetic resources" and "not to impose restrictions that run counter to the objectives of the Convention".[25]

All member countries of the World Trade Organization are obliged to develop, in the coming years, intellectual property rights protection for plant varieties. The agreement on trade-related aspects of intellectual property rights (TRIPs Agreement) requires countries to establish intellectual property right systems, including patents, for most inventions. Parties may exclude from patentability "plants and animals other than microorganisms, and essentially biological processes (...)". However members shall provide for the protection of plant varieties, "either by patents, or by an effective *sui generis* system or any combination thereof". Many countries are expected, therefore, to adopt plant breeders' rights, as provided for in the UPOV Conventions, or develop their own *sui generis* systems.

Even when there are no formal restrictions to access, the choice of planting material available to farmers may, in some cases, be severely limited due to practical constraints. Moreover, resource-poor formal-sector seed systems may not be able to provide farmers in marginal production areas with seed or planting material of the required crops and varieties of sufficient quality at the right time (see Chapter Four, Section 4.3.4). This may be particularly acute in areas where the local capacity for PGRFA management is weak (see Chapter Two, Box 2.2).

**Box 7.3 Impact of IPRs on access to PGRFA**

**Plant breeders' rights**

The holder of Plant Breeders' Rights over a variety can prevent others from reproducing it for commercial purposes, without prior agreement. However their use for research and breeding purposes is unrestricted.[26] Accordingly, plant breeders' rights are not regarded as limiting access to plant genetic resources *per se.*.[27] In some systems of plant breeders' rights, such as that provided for under the UPOV 1978 Convention, farmers are permitted to re-use saved seed freely. In other cases, such as that provided for under the UPOV 1991 Convention, such use is not allowed unless specifically provided for under national legislation.

**Patents**

Specific genes and genetic characteristics may now be subject to patent protection which could limit their availability (see Annex 1-4). Furthermore, the use of patented biotechnological products (e.g. transgenes) in varieties protected by plant breeders' rights could lead to increased complications of access to improved plant genetic resources for further improvement or breeding.

**Trade secrets**

Trade secrets are sometimes used as an alternative means of protection. For instance, while hybrid seed produced from inbred lines is accessible by purchase from a seed supplier, the inbred lines which have been developed to produce such seed are generally the trade secrets of plant breeding companies and are not accessible.

## 7.3.4 Regulation of access

Until recently, access and exchange of PGRFA have been handled more or less at the level of technical or scientific cooperation. As noted in Chapter Five (Section 5.4.1), policies concerning access to plant genetic resources are currently in a state of flux. Although only a few countries have established legislation covering access to plant genetic resources,[28] many are now reviewing their policies in this respect. In the meantime, the situation at the national level is often unclear. Few countries have defined terms of access or enacted procedures for Prior Informed Consent. Some have considered or adopted temporary measures which restrict access to plant genetic resources. Others have confirmed that they will allow free access to genetic resources under their jurisdiction. Several countries have indicated the need to develop legislation governing collecting activities and access to genetic resources *in situ*.[29] The FAO Code of Conduct for Collection and Transfer of Germplasm, adopted in 1993, serves as a point of reference until such time as countries establish their own codes and regulations.[30] Some governments are using the FAO Code as a framework in developing national regulations (see Sections 5.4.1 and 6.5.2.).

Throughout the preparatory process for the International Technical Conference, the importance of maintaining access to genetic materials was emphasized. Given the interdependence of countries and regions for PGRFA (see Chapter One), there is a need for international cooperation to facilitate access to and exchange of PGRFA. Countries have demonstrated a general willingness to continue to share resources within regions as well as globally.[31] It was emphasized, however, that there must also be a fair and equitable sharing of benefits derived from the utilization of PGRFA, in line with the Convention on Biological Diversity.[32]

The hope was expressed in several sub-regional meetings that a multilateral agreement on access be developed, in the context of the revision of the International Undertaking.[33] It has been suggested that such an agreement should facilitate access (by avoiding any need for restrictions at the point of access) while providing mechanisms for the fair and equitable sharing of benefits in those cases where profits are derived from the exploitation of the resources.[34] Such ideas are being considered by the Commission on Genetic Resources for Food and Agriculture in the course of the ongoing negotiations for the revision of the International Undertaking.[35]

#### Actions to facilitate access to PGRFA

A number of actions have been identified in this work which would help facilitate access to plant genetic resources for plant breeding. These include:

- better characterization and evaluation of PGRFA collections, and the development of core collections (Chapters Three and Five);
- better information and documentation (Chapter Three). This would allow more informed access to stored germplasm. Better passport data and documentation systems, which allow for the monitoring of transfers of samples of plant genetic resources, could also facilitate mechanisms for the sharing of benefits derived from the use of PGRFA;
- rationalization of *ex situ* collections and actions to ensure the security of existing collections (Chapter Three). This would ensure safety duplication, while reducing redundancy in collections and, thereby, facilitating searches for unique material;

- expansion and further development of the International Network of *Ex Situ* Collections under the auspices of FAO (Chapters Three and Six). This would guarantee the availability of germplasm to potential users, while protecting the rights of source countries;
- development of crop-specific networks (Chapters Four and Six). This would bring together crop experts and the users of crop-specific germplasm to provide an overview of the diversity available for each crop, and help establish priorities for its conservation and use.

A number of additional activities to increase the availability of PGRFA to farmers were identified, including:

- support of small-scale seed production and distribution enterprises (Chapters Three and Five);
- facilitation of access by farmers to a wider range of planting material, including to landraces stored *ex situ* for multiplication and distribution (Chapter Three).

## 7.4 BENEFITS DERIVED FROM THE CONSERVATION AND UTILIZATION OF PGRFA

### 7.4.1 Global benefits derived from the conservation and utilization of PGRFA

Continued conservation and utilization of PGRFA are vital to support sustainable agriculture and world food security. They can also contribute to economic growth, the alleviation of poverty and environmental protection. Chapter One provides examples of the contribution of plant genetic resources to agricultural production, yield stability, and reduced dependence on agro-chemicals. The difficulties in evaluating PGRFA were also discussed in Chapter One. There are similar problems in evaluating the benefits of their conservation and utilization. Since agriculture cannot continue without the continued conservation and utilization of PGRFA, the benefits derived are immense and perhaps unquantifiable. Determination of the costs of PGRFA conservation and utilization is also difficult. As discussed in Section 7.5, total global expenditure is probably in the order of USò 1,000 million annually - a minute amount in comparison with the global worth of agriculture.

Formal economic analysis of conservation and utilization of PGRFA is still in its infancy and further research is required to provide better estimates of the costs and benefits involved (see Annex 1-4). However, some estimates have been made of the marginal costs and benefits of particular PGRFA conservation and utilization activities. For example, the benefits derived from the collecting, storage and evaluation of an extra accession to the global rice collection has been estimated to be worth between US ò2,500 and ò5,000 per year which is between ten and 100 times the cost involved.[36] The accumulated benefits derived from the Indian rice collection have been estimated to be worth US ò75 million, compared to annual costs of about USò 300,000.[37] Similarly, the benefits derived from the increased exchange of genetic resources and improved varieties through INGER are estimated to be worth at least US ò2,000 million, more than 100 times the cost.[38]

As noted in Chapter One, the value of making wheat germplasm available to developed countries through CIMMYT has been estimated to be worth from US ò300 million to as much as US ò11 billion; an averaged estimate of US ò3 billion would represent a hundred-fold return on investment. Donors thus realize a spin-off benefit in addition to the primary purpose of such aid which is to promote agricultural development in developing countries.[39]

These examples show that cost/benefit ratios of investment in PGRFA conservation and use are very high. The same can be said for investment in agricultural research in general.[40] The World Bank recommends that each country invest at least 2% of its agricultural gross domestic product (GDP ) in agricultural research and development. Most countries fail to reach this level.

In fact, economic considerations predict an under-investment in the conservation and in many aspects of the utilization of PGRFA due to the “public good” nature of this work (see Chapter One).[41] As discussed in earlier Chapters (see Chapters Four and Five), the private sector tends to have a minimal or very limited involvement in certain types of activities. Public investment, or the creation of incentives for private involvement, are therefore required in the following activities which tend to be either long-term, or unprofitable in certain markets:

- conservation of plant genetic resources and related activities;
- evaluation and enhancement of germplasm, in particular base-broadening programmes;
- development of varieties, and production and distribution of seeds for small-scale low-income farmers, including the breeding of staple food crops for which there is little commercial incentive;
- development of network activities, including documentation systems;

- responses to emergency situations which disrupt agricultural systems;
- minimizing of risks associated with genetic vulnerability of crops due to genetic uniformity.

As discussed in Chapter One, little of the social benefits derived from the conservation and utilization of PGRFA are captured or appropriated by private bodies, and incentives are therefore weak. Plant Breeders' Rights (see Chapter Five) allow breeders to recover the costs involved in crop improvement, but no mechanisms are currently in operation to allow the farmer-conserver or farmer-breeder to benefit fully from the value of supplied germplasm. Specific measures may be needed in order to ensure the fair and equitable sharing of benefits.

In this respect, however, it should be noted that the aggregate financial benefits realized by plant breeders and seed companies are modest. Redistribution of these commercially realized benefits would not result in substantial sums of money (Box 7.4). The social benefits derived from the use of PGRFA, however, are far greater than the profits of seed sellers.[42]

The major benefits derived from the use of PGRFA in breeding have been the increase in food supplies using available resources, thus reducing food prices or preventing food price increases which would otherwise have occurred as demand increased in line with the growing world population.[43] Thus, the major beneficiaries of the use of PGRFA are food consumers in both developed and developing countries. Economists assume that most of the benefits are passed on to the consumer because both private plant breeders and farmers generally operate in more or less competitive markets. It may be expected, therefore, that breeders capture little "surplus value" from PGRFA. The data on commercial seed sales, in fact, bear this out. Similarly, farmers, as users of improved varieties, are not, as a group, expected to accumulate large benefits, though some farmers may gain and others may lose.[44] This issue is discussed further in Section 7.4.3.

### 7.4.2 The state of benefit-sharing between countries

The Convention on Biological Diversity requires Contracting Parties to take measures to share the benefits, including the results of scientific research and the benefits derived from commercial and other uses (Box 7.4). This provision makes specific reference to other articles of the Convention on access to and transfer of technology, biotechnology and the Convention's financial mechanism. Other articles of the Convention refer to the exchange of information, and scientific and technical collaboration. Thus, while the Convention does not provide a definitive list of benefits derived from the use of PGRFA, it does provide some indication as to the nature of benefits which are expected to be shared.

**Box 7.4 Sharing the benefits of PGRFA: how much can bilateral arrangements deliver?**

The commercial seed industry has an annual turnover of about US$ 15 billion per year. If 1% of these sales were to be redistributed to the providers of genetic resources (or to support programmes for the conservation and utilization of PGRFA), about US$ 150 million would be available each year.[45] This would amount to about 10% of net profits.[46]

About 5,000 new varieties are registered each year and protected by plant breeders' rights.[47] Each one is the result of a large number of crosses of material supplied by several countries.[48] Assuming that, on average, each new variety is based on PGRFA supplied by ten countries, bilateral benefit-sharing arrangements would only provide, again on average, about US$ 3,000[49] to each source country. This would be less than the transaction costs involved in administering such a benefit-sharing mechanism. Therefore, without a substantial increase in the sale price of new varieties, such bilateral mechanisms are likely to be worthwhile only under exceptional circumstances.

The relatively small amounts of money involved in the exploitation of PGRFA can be contrasted with the situation in the pharmaceutical sector, the annual turnover of which is in the order of US$ 235 billion. Far fewer new pharmaceutical products are registered each year, and most plant derived pharmaceutical products are based on material from a single source.[50] Redistribution of 1% of drug sales derived from plants could deliver several million dollars to some source countries under bilateral arrangements.[51]

In the following discussion, benefits accruing to countries are surveyed according to the following categories: (i) access to germplasm and improved varieties, (ii) other forms of technology transfer, (iii) scientific collaboration, and (iv) capacity-building. The transfer of funds is considered in Section 7.5.

The International Undertaking also calls for the strengthening of capabilities of developing countries with the aim of enabling countries to make full use of plant genetic resources for the benefit of their agricultural development,[52] and, through the resolution on Farmers' Rights, for countries in all regions to participate fully in the benefits derived from improved use of plant genetic resources.[53]

### Access to germplasm and improved varieties

Perhaps the most important benefit countries receive is access to germplasm itself, as both material stored in *ex situ* collections and improved varieties.

The extent of genetic resource exchanges, both unimproved and improved, was outlined in Section 7.3. Most countries, in their Country Reports, acknowledge that they have benefited from the use of PGRFA in crop improvement, through increases in productivity and improved resistance to pests, diseases and adverse growing conditions, and that this has contributed to their economic and social development.[54] Some countries emphasize the contribution made to the development of plant breeding industries.[55] Others cite the importance of PGRFA for the sustainability of agriculture.[56]

An example of the benefits derived from the use of new varieties is that of CIMMYT-based wheat germplasm.[57] During the 1980s, an additional 16 million hectares in the developing world — mostly non-irrigated — were sown to new wheat varieties. Using these newer varieties, farmers raised their yields by about 1% every year. In 1990, developing country farmers, who used new varieties of spring bread wheat, harvested an extra 15.5 million tonnes of grain, worth about US ò3,000 million at 1990 prices. The superior disease resistance of the newer wheats is also significant. In the large areas throughout the world where farmers grow spring bread wheat under irrigation, resistance to one disease alone - leaf rust - is worth about USò150 million each year.

In most countries, both indigenous and imported PGRFA have been used to develop new varieties. In their Country Reports, Ethiopia emphasizes the importance of the former, while Turkmenistan, which does not have a well-established PGRFA programme, states that it is difficult to imagine development of any branch of its plant industry without introduction of plant genetic resources.

The data provided in the previous section show how the development of rice varieties is largely dependent on imported germplasm. Each variety of rice released has been estimated to be worth an average of US ò2.5 million per year.[58] The high-yielding varieties of rice distributed by IRRI in the early 1970s have allowed Indonesia to become self-sufficient in rice production since 1983. Over 80% of the wheat area sown in Latin America is sown with varieties bred with CIMMYT-developed germplasm.

**Benefits appropriated through plant breeders' rights (PBR)**

As noted above, only a fraction of the social benefits derived from the use of PGRFA are appropriated, although plant breeders' rights allow breeders to recover royalties on the varieties they develop. Currently, PBR systems operate mostly in developed countries. Most PBRs, and therefore most of the direct financial benefits appropriated through this mechanism, accrue to a very small number of countries and private concerns within them: over 80% of PBRs are awarded in just seven countries (Figure 7.2). Currently, most sales of protected varieties take place in developed countries, so this does not necessarily represent a large transfer of payments from developing countries to developed countries. This situation could change, however, as more developing countries introduce plant breeders' rights, or similar systems to protect plant varieties, in line with the TRIPs Agreement. On the one hand, such countries would then be obliged to give appropriate recognition to plant breeders' rights protected in other countries and this may lead to a increased transfer of payments to countries with strong commercial plant breeding sectors. On the other hand, the introduction of plant breeders' rights may, in some countries, stimulate the development of domestic private plant breeding companies.

**Plant breeders' rights awarded from 1989 to 1993**

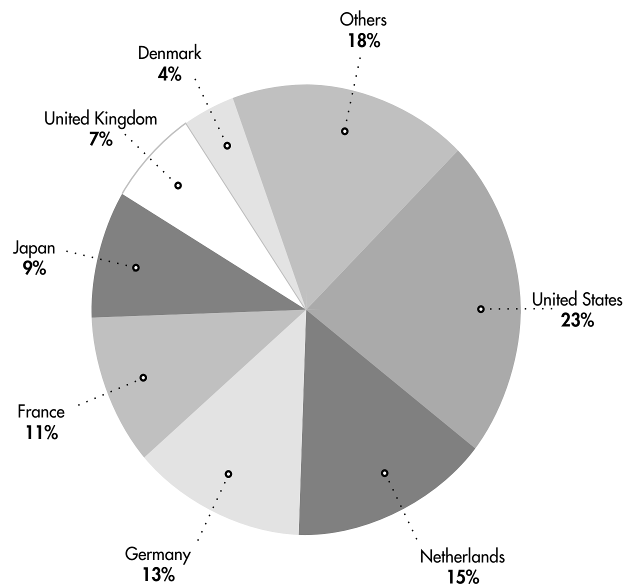



Figure 7.2 *Source:* UPOV PVP Gazette and Newsletter, May 1995

## Other forms of technology transfer

Collaboration between countries and the international and regional centres has for the most part involved germplasm collection, germplasm exchange and training. Little detailed information is available, however, concerning the transfer of technologies for the conservation and utilization of PGRFA, other than the transfer of improved varieties. Nevertheless, some countries have indicated the need for technologies other than the transfer of improved germplasm. These include *in vitro* conservation and propagation techniques, and other methods used for the conservation of non-orthodox seeded and vegetatively propagated plants,[59] documentation systems[60] and geographical information systems (GIS).[61] Most of these technologies are in the public domain. Some countries also emphasize the transfer of biotechnologies,[62] some of which are protected by intellectual property rights. (This applies also to many products of biotechnology derived from plant genetic resources and used for plant improvement. For example, isolated transgenes, molecular markers and probes are now increasingly under patent protection.) Chapter Six (Box 6.2) provides information on international cooperation and biotechnology transfers. The Convention on Biological Diversity requires parties to facilitate the transfer of these technologies, including those controlled by the private sector (see Box 7.1) and those protected by intellectual property rights.[63] During the preparatory process for the International Technical Conference, countries called for attention to technology development and the promotion of mechanisms to facilitate the transfer of technology for the conservation and utilization of PGRFA between and among member countries.[64]

### Scientific collaboration

A number of countries emphasize the importance of collaboration in scientific research, including joint ventures.[65] Thailand reports that collaborative work can shorten the time required for the development of new varieties. Namibia reports that the costs of collecting and maintaining collections can often be covered by international collaborators. Regional collaborative projects result in shared project costs and opportunities, for example, for evaluating germplasm over a wide geographic range and improving the exchange of information and technology.[66] In the case of the SADC plant genetic resources programme collaborative project, the regional genebank has the potential of maintaining the base collections of the collaborating countries, allowing the national genebanks to focus on handling active or working collections. Regional cooperation is discussed in Chapter Six.

Some countries, however, indicate that their research priorities are not always met by such collaborative projects. Many developing countries have numerous crops which have not been developed to a level which will attract support from commodity-based international institutions. A number of countries have therefore called for the mandates of the CGIAR Centres to be broadened to include crops such as sunflower, castor,[67] taro,[68] tropical fruits,[69] tropical industrial crops[70] and a wider range of under-utilized species.[71] In addition, it is noted that, for the crops covered by the IARCs, farmers' specific needs and quality preferences are not always taken into account by existing research programmes.[72]

### Capacity-building

A major benefit of international collaboration in PGRFA conservation and use is training and other forms of capacity-building. Through the CGIAR, for example, and in collaboration with national programmes, several thousand people from developing countries, as well as a large number from developed countries, have been trained in plant genetic resources conservation. All the centres concerned with crop improvement have significant training programmes in the conservation and, especially, the development and use of genetic resources.[73] New genebanks have been built in several countries with bilateral and multilateral support, including in Argentina, Chile, Ethiopia, India, Kenya, Pakistan, Sri Lanka, the Syrian Arab Republic, Thailand and several countries in Southern Africa.

National capacities in many developing countries, however, remain insufficient. The capacities of countries with respect to the various activities of PGRFA conservation and utilization were reviewed in Chapters Three, Four and Five. Most countries have identified a need for further capacity-building, including training of national staff in various aspects of plant genetic resources management.[74]

### Assessment of the current state of benefit-sharing between countries

The benefits derived from PGRFA are great and spread widely. Only rarely are they appropriated by those most closely involved in the conservation and development of PGRFA. Also, insufficient national capacity often limits the benefits that can be derived at the country level. This may also be exacerbated by poor linkages between conservation and utilization activities (see Chapter Five). For these reasons, some countries rich in indigenous PGRFA report that greater benefits may be realized outside rather than within the country.[75]

In this book, a number of actions have been identified which would contribute to improving the capacity of countries to realize benefits from the utilization of PGRFA. These include:

- strengthening coordination at the national level, including through the development of programmes, plans and legislation;
- improving linkages between conservation and utilization (Chapter Four);
- strengthening national capacities in conservation and crop improvement (Chapters Two, Three and Four);
- training (Chapter Five);
- rationalization of conservation efforts to share burdens and reduce costs (Chapter Three);
- enhancing international support, including through the further development of the Global System (Chapter Six).

### 7.4.3 The state of benefit-sharing with regard to farmers and communities

FAO Conference Resolution 5/89 on Farmers' Rights specifically refers to the need for "farmers" and "their communities" as well as "countries in all regions" to participate fully in the benefits derived from the improved use of plant genetic resources (see Box 7.2).[76] The Convention on Biological Diversity requires countries to encourage the equitable sharing of the benefits arising from the utilization of the knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant to the conservation and sustainable use of biological diversity.[77] During the preparatory process for the International Technical Conference, it was emphasized that rural communities should benefit from the realization of Farmers' Rights.[78]

Little information on the sharing of benefits within countries is provided by Country Reports, and few countries report any specific benefit-sharing mechanisms within countries. However, during the preparatory process, countries identified the need to develop programmes and projects which allow farmers and communities to participate more fully in the benefits derived from the conservation and use of PGRFA. It was also proposed that the possibility of developing legal mechanisms to protect the varieties and knowledge of farmers and rural communities be explored. These two approaches are examined below.

#### Development of *sui generis* systems, intellectual property rights and other legal mechanisms to benefit farmers and communities

During the preparatory process, a number of countries called for Intellectual Property Rights to be adjusted to recognize Farmers' Rights and the rights of local peoples with regard to traditional resources, as well as the sovereign rights of gene-donor countries.[79]

In most developing countries, agricultural plant varieties are not covered by any form of intellectual property protection. Efforts are now under way, however, to develop *sui generis* systems for plant variety protection, in line with the Agreement on Trade-Related aspects of Intellectual Property rights (see also Chapter Five). Some countries are also considering incorporating into these systems mechanisms for the sharing of benefits with farmers and communities. India, for example, is considering the possibility of building upon features of the 1978 UPOV Convention (including the farmers' privilege which allows the reuse of farmer-saved seed) to entitle farmers to compensation for protected varieties. The stated aim is to balance breeders', farmers' and researchers' rights in this area, by recognizing and rewarding informal innovations by farming families. A share of the royalties for a protected variety would be reserved for the farming communities that provided the PGRFA used in developing the protected variety. Where such communities cannot be identified, a share of the royalties would be paid into a fund to promote PGRFA conservation and use by small-scale farmers. The scope of such proposed legislation would be national, but India also calls for international mechanisms to promote benefit-sharing.

In the Philippines, there are also a number of relevant bills pending in Congress. One would provide for the establishment of a system of community intellectual property rights protection, another would include community intellectual property rights and Farmers' Rights in proposed legislation to protect plant breeders' rights.[80]

### The development of projects and programmes to benefit farmers and their communities

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 material and reaping the benefits to be derived from it.

At present, many 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 System. However, many farmers, particularly those who operate in economically marginal areas, often do not benefit in this way. Yet, as already noted, these tend to be the farmers and communities most involved in conserving, developing and making PGRFA available. A number of needs have been identified in this Report to strengthen the involvement of such farmers in the conservation and utilization of PGRFA, and, thereby, facilitate more effective sharing of benefits. Specifically, the need to develop farmer participation in plant genetic resource management was discussed, including greater involvement of local communities in the designing of *in situ* strategies.[81] Other needs identified include the following:

- greater emphasis on minor crops and under-utilized species in research, development and marketing (Chapters One and Four);
- facilitating, where appropriate, the direct use of landraces and other material conserved in genebanks by farmers (Chapters Two and Four);
- strengthening *in situ* management of PGRFA (Chapter Two);
- decentralized and participatory approaches to plant breeding (Chapters Two and Four);

- strengthening farmer-level seed production and distribution mechanisms (Chapters Two and Four);
- strengthening links between the formal and informal sectors (Chapters Two, Four, and Five).
- establishment of rehabilitation mechanisms (Chapter Two).

During the preparatory process for the International Technical Conference, a number of countries called for international funding of such activities, as identified in the Global Plan of Action, as a contribution to the realization of Farmers' Rights.[82] Earlier, the Commission on Genetic Resources for Food and Agriculture stated that in the Global Plan of Action "particular attention should be given to supporting farmers and their communities directly", and to "improving the use of genetic resources to promote sustainable agriculture in marginal areas".

## 7.5 FINANCING PGRFA ACTIVITIES

The Convention identifies three types of funding: national or domestic expenditures, the financial mechanism of the Convention, and other bilateral and multilateral flows.[83] In this section, an attempt is made to assess the current level of funding for the conservation and utilization of PGRFA. Expenditures on PGRFA are difficult to assess, however, largely because of the lack of consistency in defining the scope of PGRFA programmes, and due to different methods of accounting and reporting.

As part of the preparatory process, countries were asked to report domestic expenditure on PGRFA-related activities. In extrapolating information from the 34 countries which responded on this matter, it was estimated that about US ò600 million is spent annually on "PGRFA activities".[84] This figure, however, is subject to wide error, as the scope of activities included in each country's assessment varied considerably. Some countries considered only national PGRFA programmes, specifically *ex situ* conservation efforts. Others included aspects of *in situ* conservation and utilization as well. Overall, the estimated US ò600 million probably represents a moderate overestimate of expenditures for PGRFA conservation, while it certainly falls far short of the total spent on PGRFA utilization in the broad sense, i.e. including plant breeding and seed production. The total annual expenditure on PGRFA conservation and utilization can only be guessed at, perhaps US ò1,000 million or so. More reliable information is clearly required. In comparison, total public-sector investment inagricultural research worldwide is about US ò26,000 million. Of this, ò17,000 million is spent in developed countries, ò8,700 million in developing countries, and an additional US ò286 million by the CGIAR. In addition, an estimated ò10,000 million is spent on agricultural research and development by the private sector, mainly in developed countries.[85]

Official development assistance is the best documented source of financial flows, although it is hard to define the proportion assigned to PGRFA. Total aid flows have been falling in recent years, as has the share of agriculture in total development finance. After the food crisis in the early 1970s, annual commitments for agriculture rose to around US ò10,000 million (at current dollar rates); this increased to about ò14,000 million at the end of the 1980s. Since then, there has been a steady decline, to around ò10,000 million at present. Funding for the CGIAR, though it represents only a very small share of this total (4%), has mirrored this pattern. Funding for biodiversity conservation, on the other hand, has increased, but this represents only a relatively small level of expenditure. The Global Environment Facility (GEF), for example, disburses about USò 60 million per year on biodiversity-related projects, and it is estimated that only about US ò7 million is devoted annually to PGRFA-related activities.[86]

The survey of countries indicated that about US ò190 million is contributed each year for PGRFA-related multi- and bilateral international activities, though this is likely to be an underestimate for the same reasons quoted earlier. A separate survey of multilateral agencies suggests that about ò140 million per year is channelled through international organizations, including the CGIAR. About ò106 million is spent by the IARCs on PGRFA-related activities, of which about ò35 million is devoted to *ex situ* conservation.[87] The World Bank, other development banks and the International Fund for Agricultural Development (IFAD) are major players in agricultural development projects and NARS capacity-building. However, it is difficult to assess the proportion related to PGRFA conservation and utilization.

During the preparatory process for the International Technical Conference, the shortage of funding was identified as a major constraint. While many PGRFA conservation and utilization activities are long-term and require sustainable funding, international funding is often short-term and insufficient. There is a clear need for funding on a planned and sustainable basis. This could be provided by both new and additional funding as well as through a reallocation of resources. It was recognized, however, that international funding does not remove the need for domestic funding. It is widely agreed that a national commitment to provide sustainable funding for national programmes and projects through specific funding allocations from governments is essential.[88]

## 7.6 IMPLEMENTATION OF FARMERS' RIGHTS

As noted in Chapter One, economic analyses support the view that many of those engaged in conserving and developing PGRFA, particularly farmers and their communities, do not receive benefits proportionate to their efforts.[89] This has been recognized by countries through the FAO Resolution on Farmers' Rights (see Box 7.2) which calls for farmers and their communities to participate fully in the benefits derived from the use of plant genetic resources.

The realization of Farmers' Rights has been called for by UNCED in its Agenda 21,[90] and by the Conference for the Adoption of the Text of the Convention on Biological Diversity.[91] In response to these requests, the FAO Conference, in 1993, adopted Resolution 7/93 calling for the re-negotiation of the International Undertaking, including the realization of Farmers' Rights. This process has received the support of the Conference of the Parties to the Convention on Biological Diversity.[92] During the preparatory process for the International Technical Conference, countries emphasized the need to realize Farmers' Rights.[93]

### Implementation of Farmers' Rights through an international fund and the Global Plan of Action

It has been agreed that one of the ways Farmers' Rights should be implemented is through an international fund and other funding mechanisms (Box 7.2).[94] As defined by the Farmers' Rights resolution, the fund could assist farmers and farming communities in the conservation of their plant genetic resources, and allow them and their countries to participate fully in the benefits derived from the improved use of plant genetic resources, through plant breeding and other methods. The Global Plan of Action is intended as a guide for international cooperation on PGRFA, including the establishment of funding priorities.

The need for international financing in support of the Global Plan of Action was highlighted during the preparatory process.[95] The need for donors and recipients of funds to cooperate to improve efficiency, reduce duplication of efforts and carefully allocate available financial resources was noted. Further, it was proposed that donors' contributions to the Global Plan of Action should be in line with the priorities and criteria of the Plan. It was reiterated that the Commission on Genetic Resources for Food and Agriculture should oversee the policies, programmes and priorities for funding.[96] It was further suggested that priority in funding should be given to programmes and projects which are part of a coherent national plan, and that special priority be given to projects that have been planned and agreed upon at the regional or sub-regional level.

### Aspects of Farmers' Rights still under discussion

The concept of Farmers' Rights may include several dimensions: compensation for innovation in the development of farmers' varieties; compensation to farmers for making plant genetic resources available; provision of incentives for continued conservation of these resources; and support for particular conservation and utilization activities.[97]

During the discussions and on-going negotiations for a revised International Undertaking,[98] and during the preparatory process for the International Technical Conference,[99] it has been suggested that Farmers' Rights may have other operational dimensions including:[100]

- the traditional rights of farmers and their communities to keep, use, exchange, share and market their seeds and plant reproductive material, comprising the right to re-use farm-saved seed known as the "farmers' privilege";
- the needs of farmers and their communities as custodians of plant genetic resources and related indigenous and local knowledge (in line with Article 8(j) of the Convention) to have their rights protected and to share in the benefits derived therefrom.

Some non-governmental organizations have also proposed that Farmers' Rights be developed as a "bundle of rights", including rights to conserve, develop and protect plant genetic resources, the right to receive financial support for conservation and utilization activities, the right to benefit from the commercial exploitation of resources under their stewardship, and the right to determine the extent to which such resources and related practices, information and knowledge are made available.[101]

Many countries argue that there is a need for a legal framework for the implementation of Farmers' Rights. Some have proposed that such a framework first be developed at the international level. Some countries have also suggested that certain aspects of Farmers' Rights be protected through the development of intellectual property rights, or similar systems, to protect indigenous knowledge. (The difficulties of such an approach are explored in Annex 1-4.) Some countries consider that the implementation of certain aspects of Farmers' Rights could be facilitated through an appropriate *sui generis* system, in line with the TRIPs agreement. Such an approach could incorporate the "farmers' privilege" (as is already the case with the UPOV 1978 Convention), and could also include benefit-sharing mechanisms, such as those under consideration in India. Benefits might be awarded to particular farming communities or accrue to a fund. All of these matters are under discussion in various forums, including FAO in the context of the renegotiation of the International Undertaking.

## 7.7 CONCLUSIONS

The benefits derived from the conservation and utilization of plant genetic resources for food and agriculture are immense and widely spread. PGRFA contribute to increased productivity and sustainability of agricultural systems and lower food prices.

There are few incentives for private investment in either long-term PGRFA conservation or many aspects of utilization. Continued public-sector investment will be required to ensure a continued flow of benefits. Furthermore, increased efforts will be needed to meet the challenges of ensuring food security in the face of a rapidly growing world population.

All countries are heavily dependent upon PGRFA originating in other parts of the world. Benefits realized through the conservation and utilization of PGRFA have been based on wide availability of plant genetic resources, including enhanced germplasm and finished varieties.

Access to a wide range of plant genetic resources is therefore paramount. The issues of access to PGRFA and the sharing of benefits, as well as the subject of Farmers' Rights, are currently being discussed in the context of the revising of the International Undertaking on Plant Genetic Resources.

Benefit-sharing can be promoted both by legal mechanisms and through well directed programmes and projects. Many of the actions identified in this Book and summarized in this Chapter could contribute in a practical way to the sharing of benefits in line with the current FAO Resolution on Farmers' Rights. The Global Plan of Action, adopted by 150 countries at the International Technical Conference on Plant Genetic Resources in Leipzig, Germany, in June 1996, can be viewed as a contribution to the realization of Farmers' Rights (Box 7.5).

The Global Plan of Action was endorsed by the FAO Council[102] and the Conference of the Parties of the Convention on Biological Diversity.[103] At the World Food Summit convened by FAO in Rome, November 1996, Heads of State and Government committed their countries to implement the Global Plan of Action.[104]

### Box 7.5 Priority activities of the Global Plan of Action[105]

***In situ* conservation and development**

1. Surveying and making inventories of PGRFA
2. Supporting on-farm management and improvement of PGRFA
3. Assisting farmers in disaster situations to restore agricultural systems
4. Promoting *in situ* conservation of wild crop relatives and wild plants for food production

***Ex situ* conservation**

5. Sustaining existing *ex situ* collections
6. Regenerating Threatened *Ex Situ* Accessions
7. Supporting Planned and Targeted Collecting of PGRFA
8. Expanding Ex Situ Conservation

**Utilization of Plant Genetic Resources**

9. Expanding the characterization evaluation and number of core collections to facilitate use
10. Increasing genetic enhancement and base-broadening efforts
11. Promoting sustainable agriculture through diversification of crop production and broader diversity in crops
12. Promoting development and commercialization of underutilized crops and species
13. Supporting seed production and distribution
14. Developing new markets for local varieties and "diversity-rich" products

**Institutions and capacity building**

15. Building strong national programmes
16. Promoting networks for PGRFA
17. Constructing comprehensive information systems for PGRFA
18. Developing monitoring and early warning systems for loss of plant genetic resources
19. Expanding and improving education and training
20. Promoting public awareness of the value of PGRFA conservation and use

## Chapter 7 endnotes

1 Formerly the Commission on Plant Genetic Resources for Food and Agriculture.

2 The fact that a nation has sovereign rights over its territory, including its natural resources, is a well established principle of international law (Resolution 1803 of the UN General Assembly stated, in 1962, that due care should be taken “to ensure that there is no impairment, for any reason, of the state’s sovereignty over its natural wealth and resources.” See also Principle 21 of the 1972 UN Conference on the Human Environment, Stockholm, which was reproduced by Article 3 of the Convention on Biological Diversity: “states have the sovereign right to exploit their own resources pursuant to their own environmental policies”.). A state has the power and jurisdiction to establish how such resources and assets, tangible and intangible, are distributed, used and, if it wishes, made subject to property rights. The first international instrument to make specific reference to the sovereign rights of states over plant genetic resources was the FAO International Undertaking on Plant Genetic Resources, in Conference Resolution 3/91, adopting what is now Annex 3 to the Undertaking.

3 Following the adoption of the original text of the International Undertaking on Plant Genetic Resources (FAO Conference Resolution 8/83), three complementary resolutions have been adopted and annexed to the Undertaking. The present Undertaking thus encompasses both the original text and the three resolutions. See also Chapter 6, section 6.4.1.

4 Article 1 states: “This Undertaking is based on the universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction.” This is detailed further in Article 5: “It will be the policy of adhering governments and institutions having plant genetic resources under their control to allow access to samples of such resources, and to permit their export, where the resources have been requested for the purposes of scientific research, plant breeding or genetic resource conservation. The samples will be made available free of charge, on the basis of mutual exchange or on mutually agreed terms.”

5 FAO Conference Resolution 3/91, Annex Three to the International Undertaking, operative paragraph 3.

6 FAO Conference Resolution 3/91, Annex Three to the International Undertaking, operative paragraph 1.

7 FAO Conference Resolution5/89, Annex Two to the International Undertaking, operative paragraph (c).

8 A complementary resolution on the Interrelationship between the Convention on Biological Diversity and the Promotion of Sustainable Agriculture was approved by the Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity as part of the Final Act of the Conference in Nairobi on 22 May 1992. This resolution noted the convening of the International Technical Conference on Plant Genetic Resources, and the elaboration through it of a Global Plan of Action, and also noted the “need to seek solutions to outstanding matters concerning plant genetic resources within the Global System for the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture, in particular:

- access to *ex situ* collections not acquired in accordance with this Convention; and
- the question of Farmers’ Rights.”

9 Decision II/15 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, Jakarta, Indonesia, 6-17 November 1995.

[10] FAO Conference Resolution 7/93.

[11] Article 1 states: *"This Undertaking is based on the universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction."* This is detailed further in Article 5: *"It will be the policy of adhering governments and institutions having plant genetic resources under their control to allow access to samples of such resources, and to permit their export, where the resources have been requested for the purposes of scientific research, plant breeding or genetic resource conservation. The samples will be made available free of charge, on the basis of mutual exchange or on mutually agreed terms."* The definition of plant genetic resources in the Undertaking included improved varieties and other research products derived from plant genetic resources, as well as wild resources and farmers' varieties, and therefore the free access provision applied equally to all. However, this position was modified by later FAO resolutions, which became annexes to the Undertaking. Resolution 4/89 in recognizing that plant breeders' rights were not incompatible with the Undertaking and acknowledged that conditions could be placed on the availability of improved varieties. Resolution 4/89 also clarified that "the term 'free access' does not mean free of charge." Resolution 3/91 stated that breeders' lines and farmers' breeding material should only be available at the discretion of their developers during the period of development.

[12] All information from respective Country Reports (China, United States, Germany, Canada, Brazil). Some information is also provided by Japan which has distributed 6,787 samples "in recent years" - the central genebank of MAFF (Tsukuba) distributed an average of 650 per year - and by Poland which distributes about 700 samples each year. This discussion refers only to international transfers of germplasm samples, for information about total distributions from genebanks, i.e. including those used domestically, please refer to Chapter 4

[13] The information, as provided by Country Reports, is as follows: Brazil 45% of samples distributed are sent abroad, Germany 39%; United States 34%; Poland 28%; Canada 19%; and Japan 9%.

[14] As indicated in Chapter 3, section 3.1, the number of unique accessions in base collections is estimated to be 1 to 2 million. The extent of redundancy within the CGIAR base collections is low. If 20% of CGIAR collections are duplicates, the total CGIAR collection would represent between 24% and 48% of distinct global accessions.

[15] Cooper D, Engels J and Frison E (1994) *A multilateral system for plant genetic resources: imperatives, achievements and challenges*. Issues in Genetic Resources No. 2, May 1994. IPGRI, Rome.

[16] SGRP (1996) *Report of the Internally Commissioned External Review of the CGIAR Genebank Operations*. International Plant Genetic Resources Institute, Rome, Italy.

[17] IPGRI (1996) *Access to plant genetic resources and the equitable sharing of benefits: a contribution to the debate on systems for the exchange of germplasm.* Rome.

[18] As noted in Chapter 1, the value of wheat germplasm made available to developed countries through CIMMYT is estimated to be between US ò300 million and US ò11,000 million.

[19] Gollin D (1996) *Valuing crop genetic resources for varietal improvement: the case of rice*. Paper presented at the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, sponsored by the Centre for International Studies on Economic Growth (CIES) of the Tor Vergata University,

> 13-15 May 1996, Rome; Evenson RE and Gollin D (1996) *Genetic resources, international organizations, and rice varietal improvement*. Economic Development and Cultural Change, Yale University and University of Minnesota, USA. There are few comparable data available for other crops.

[20] Ibid.

[21] Ibid.

[22] For example, China indicates 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).

[23] Formally, the same applies to farmers' breeding material (FAO Resolution 3/91), although in practice, much material developed by farmers has been made available without restriction.

[24] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(d).

[25] Article 15.2.

[26] Except for, in the case of material protected by legislation in line with the UPOV 1991 Convention, "essentially derived varieties".

[27] The Commission on Plant Genetic Resources found that plant breeders' rights are not incompatible with the International Undertaking, which provided for unrestricted access to plant genetic resources. FAO Conference Resolution 4/89.

[28] For example the Philippines Presidential Executive Order No. 247 (See Chapter 5, section 5.4.1).

[29] These include Angola, Egypt, Ethiopia, Mauritius, Papua New Guinea, Sri Lanka, Turkey, United Republic of Tanzania and Yemen.

[30] Subregional preparatory meeting: Southern Africa Report, para 12(vi).

[31] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, paras 13(d) and 14(ix); Subregional preparatory meeting: Southern Africa Report, para 12(vi); Subregional preparatory meeting: North America Report, recommendation (e), Regional preparatory meeting: Europe Report, recommendations 21and 22(a); Subregional preparatory meeting: West and Central Africa Report, para 38.

[32] Subregional preparatory meeting: Southern Africa Report, recommendation (vi).

[33] Subregional preparatory meeting: West and Central Africa Report, para 38; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(ix); Regional preparatory meeting: Europe, recommendation 21. At the European regional meeting it was agreed to encourage the establishment of a multilateral agreement for plant genetic resources for food and agriculture, and it was recommended:

> "(a) that this multilateral agreement include both material collected prior to the coming into force of the Convention on Biological Diversity and material collected thereafter;

(b) that this multilateral agreement include in principle all plant genetic resources for food and agriculture;

(c) that this multilateral agreement ensure unrestricted access to the plant genetic resources covered by the agreement, to all members to the agreement;

(d) that this multilateral agreement encourage the involvement of the private sector and NGOs;

(e) that, with the view to implementing the Global Plan of Action, the multilateral agreement resulting from the negotiated revision of the International Undertaking include *inter alia*, and in harmony with other relevant international agreements, the following elements:

- an information network or system, including an inventory of genetic resources, promoting information exchange on material designated to the multilateral agreement, and
- a multilateral framework to support the strengthening of technical capacity and to implement programmes which would ensure a fair and equitable sharing of benefits derived from PGRFA, contributing, *inter alia*, to the realization of Farmers' Rights".

[34] Subregional preparatory meeting: West and Central Africa Report, para 38; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(ix).

[35] During the Sixth Session of the Commission on Plant Genetic Resources (2-8 June 1995), Mr G. Hawtin, Director-General, International Plant Genetic Resources Institute (IPGRI), outlined some options concerning "Approaches to facilitating access to plant genetic resources and promoting the equitable sharing of benefits arising from their commercial exploitation, within the context of the CGIAR" (See FAO (1996) *Report of the Sixth Session of the Commission on Plant Genetic Resources*, CPGR-6/95/REP, Annex).

According to this proposal, PGRFA in the system could be used, without payment, for research and not-for-profit purposes. However, in certain cases where profits are generated through the commercial exploitation of the resources, users of samples of PGRFA would be obliged to negotiate a share of the profits with the countries of origin for material collected after the entry into force of the Convention on Biological Diversity. Definitions of "not-for-profit" use and "commercial" use would need to be agreed upon. In addition, all participating countries, but especially developing countries, would be eligible for support through the international fund (envisaged for the implementation of Farmers' Rights) to promote conservation and utilization of PGRFA as elaborated in the Global Plan of Action. Developed countries that are parties to the system would, in addition to making their own PGRFA available, contribute financially to the funding mechanism. Appropriate legal instruments, possibly including material transfer agreements (see Annex 1-4), might need to be developed to ensure compliance. Other possibilities for helping to ensure compliance may be explored including, *inter alia*, requiring disclosure of the origin of component genetic resources in all applications for intellectual property rights. Good documentation systems would also assist in the monitoring of the movement of materials and thus help minimize infringements.

> IPGRI was asked by the Commission to prepare an in-depth study of the various possible multilateral systems compatible with the Convention on Biological Diversity to be considered by the Commission on Genetic Resources for Food and Agriculture at its Third Extraordinary Session in December 1996.

36 Evenson RE (1996) *The valuation of crop genetic resource preservation, conservation and use*. Manuscript prepared for the Secretariat of the Commission on Plant Genetic Resources. Yale, USA; Evenson RE (1996) *Valuing genetic resources for plant breeding: hedonic trait value and breeding function methods*. Paper presented at the CIES Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, 13-15 May 1996, Tor Vergata University, Rome.

37 National Research Council (1993) *Managing global genetic resources: agricultural crop issues and policies*. National Academy Press, Washington, DC, USA. Note that these estimates represent the net present value of a stream of future benefits and are highly sensitive to the discount rate employed. The estimates in this paragraph are based on a rate of 10%, this is high compared to the normal expected rate of return of 3% to 5%. A high rate was used by the researchers because rates of return are consistently high for research, and they considered that the opportunity cost of investing in PGRFA conservation and utilization is to not invest in other forms of agricultural research. By way of comparison, a 5% interest rate would provide a net present value of about USò400 million. Nevertheless, since public funds will always be scarce, those funds that are available for research and development (R&D) should be allocated to the use with the highest social payoff. Pardey PG and Alston JM (1995) *Revamping agricultural R&D 2020.* Brief 24, IFPRI.

38 Op. cit., endnote 19. This is the net present value calculated at 10% discount rate. At 5% it would be USò6 million. It is a conservative estimate calculated assuming that (i) INGER merely speeds up the releases of varieties which would otherwise be released 10 years earlier.

39 Mooney PR (1993) Exploiting local knowledge: international policy implications. In de Boef W, Amanor K and Wellard K. *Cultivating knowledge*. Intermediate Technology Publications, London.

40 Most studies of the private and social rates of return to agricultural R&D have been very high - typically more than 20% per year, compared with 3% to 5% per year for the long-term, real rate at which governments borrow money. While these estimates may be subject to factors that lead to underestimation or overestimation, there is little doubt that rates of return are high and that investment in agricultural R&D is too low. Nevertheless, since public funds will always be scarce, those funds that are available for R&D should be allocated to the use with the highest social payoff. Pardey PG and Alston JM (1995) *Revamping agricultural R&D 2020.* Brief 24, IFPRI.

41 Public goods are non-rival in consumption and non-exclusive. National and international management is, therefore, generally necessary. Refer to Chapter 1 for more information.

42 Wright BD (1996) *Intellectual property and Farmers' Rights*. Paper presented at the CIES Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, 13-15 May 1996, Tor Vergata University, Rome.

43 It should also be noted that, without continued conservation and utilization of PGRFA, it would not be possible to maintain yield levels in the face of pests, diseases and other environmental challenges. Thus, investment in PGRFA has also prevented food price increases which would have occurred as a result of yield losses.

44 See Lipton M with Longhurst R (1989) *New seeds and poor people.* Unwin Hyman, London, for a discussion on the social impacts of new crop varieties on different groups of farmers.

45 Barton (1991) estimates that the total revenue that might be gained by developing countries for unimproved germplasm would amount to less than USò100 million annually. Note, however, that a percentage share of profits would yield much lower levels. Assuming a profit rate of 5%, a 5% share of profits would yield only about ò40 million a year, for example.

46 For example, in the period 1993 to 1995, Pioneer International Hi-Bred recorded operating profits of about USò300 million per annum, on a turnover of about ò1,500 million, i.e. a pre-tax profit rate of about 20%. Net (post-tax) profits averaged about USò170 million, or 12% of turnover.

47 An average of 4,750 plant breeders' rights certificates were issued per year from 1989 to 1993, showing an upward trend (5,789 certificates were issued in 1993). UPOV (1995) Plant variety protection. *Gazette and Newsletter of the International Union for the Protection of New Varieties of Plants*, No. 77, May 1995, UPOV publication No. 438, Geneva.

48 For example, the VEERY wheat lines released by CIMMYT in 1977 were developed from approximately 3,170 crosses, made between 51 individual parents originating in 26 countries around the world. Op. cit., endnote 17.

49 This estimate is calculated as follows: USò150 million is divided by 5,000 (number of new varieties protected each year), and then divided by 10 (estimate of number of source countries contributing to each variety). 150,000,000/5,000x10) = 3,000.

50 Patents in the United States are sought on most of the valuable new pharmaceutical products. In recent years, about 23 new products for human use are registered by the Food and Drugs Administration each year. Simpson D, Sedjo RA and Reid JW (1996) Valuing biodiversity for use in pharmaceutical research. *International Journal of Political Economy,* 104:163-185.

51 Op. cit., endnote 42. Thus far, benefit-sharing arrangements have been based on less than 5% of profits, which is much less than 1% of sales. ten Kate, K (1995). *Biopiracy or green petroleum? Expectations and Best Practice in Bioprospecting.* UK Overseas Development Administration, London.

52 Article 6 of the International Undertaking.

53 FAO Resolution 5/89, Annex 2 of the International Undertaking on Plant Genetic Resources.

54 For example, Country Reports China, Bangladesh, the Philippines, Thailand, Israel, Canada, Czech Republic, Slovakia.

55 For example, the Israel Country Report states that improved hybrid vegetable seeds are a major Israeli export, while the United Kingdom Country Report mentions the support to institutes such as the Scottish Agricultural Science Agency (SASA) and the Horticultural Research Institute (HRI).

56 Country Report Germany.

57 Based on Byerlee D, and Moya P (1993) Impacts of international wheat breeding research in the developing world, 1966-1990. *Journal of Development Economics*, 39:365-387.

58 Evenson RE and David CC (1993) *Adjustment and technology: the case of rice.* OECD Development Centre series, Paris.

[59] Country Reports Nepal, Bangladesh, Seychelles, Tonga, Papua New Guinea, Ghana, Islamic Republic of Iran, United Republic of Tanzania.

[60] Country Report Bangladesh.

[61] Country Report Turkey.

[62] Country Reports Turkey, Islamic Republic of Iran, Nepal, Bangladesh.

[63] The Convention addresses the issue of intellectual property rights (IPRs) in respect of access to and transfer of technologies in Article 16. On the one hand the Convention states that "such access and transfer shall be provided on terms which recognize and are consistent with the adequate and effective protection of IPRs" (Art. 16.2). On the other hand the Contracting Parties that provide genetic resources are to be "provided access to and transfer of technology which makes use of those resources... including technology protected by patents and other IPRs" (Art. 16.3). Thus, while IPRs may be recognized, mechanisms might be developed to ensure that they do not provide a barrier to technology transfer. Article 16, paragraph 3, suggests that the financial mechanism may be used to facilitate this (presumably this could include payment of IPR royalties). The Convention also calls for cooperation to ensure that IPRs are supportive of and do not run counter to the objectives of the Convention (Art. 16.5).

[64] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 14(xi); Subregional preparatory meeting: Southern Africa Report, para 12(xii).

[65] For example, see Country Reports Namibia, Egypt, Thailand.

[66] As reported by countries of the European Union.

[67] Country Report the Sudan.

[68] Country Reports Samoa, Seychelles.

[69] Country Report Mauritius.

[70] Country Report Malaysia.

[71] Country Reports India, United Republic of Tanzania.

[72] Country Reports the Sudan, Sierra Leone.

[73] Article 12 of the Convention on Biological Diversity requires Contracting Parties to "establish and maintain programmes for scientific and technical education and training in measures for the identification, conservation and sustainable use of biological diversity and its components."

[74] A particular need identified by many countries is for training and, in some cases, infrastructure development in relation to biotechnology (the Gabon, Kenya, Seychelles, Zambia, Democratic Republic of Congo, Zimbabwe, Nigeria, Grenada, Bolivia, Cook Islands, Cambodia, the Philippines, Lithuania, Ukraine). A number of countries have identified the need to establish or upgrade *in vitro* facilities for conservation purposes, including cryopreservation, propagation and research (Nepal, Lithuania, Russian Federation, Greece, Syrian Arab Republic, Turkey, Ireland, Kenya, Lesotho, Malawi, Côte d'Ivoire, Congo, Ghana, the Niger, Togo, Costa Rica, Mexico). Several countries also recognize the need to develop or improve quarantine facilities including the capacity to carry out virus indexing (Russian Federation, Botswana, Lesotho, Côte d'Ivoire, Ghana, the Niger, Cuba). Training needs were also identified in areas such as botany and taxonomy (the Gabon, Kenya, Botswana, Zambia, Zimbabwe, Togo, Saint Kitts and Nevis, Cambodia, Yugoslavia, Morocco), genetics and plant breeding (including the Gabon, the Sudan, Namibia, Zambia, Zimbabwe, Honduras, Cambodia, Poland), plant health (the Gabon, Kenya, Gambia, Togo, Saint Kitts and Nevis, Cambodia),

> documentation and information systems (the Gabon, Kenya, Mauritius, Togo, Honduras, Guyana, Saint Kitts and Nevis, Argentina, Bolivia, Cook Islands, Cambodia, Estonia, Lithuania, Ukraine). Many countries also request assistance with the development of policies and legislation relating to access and exchange of germplasm (Cameroon, the Gabon, Eritrea, Bolivia, Tunisia). Further details of the major needs and opportunities in relation to training are covered in Chapter 5, Section 5.3.[76] For example: Sub-regional preparatory meeting: Mediterranean Report, para 30; Country Report Ethiopia.

75 For example: Subregional preparatory meeting: Mediterranean Report, para 30; Country Report Ethiopia.

76 FAO Conference Resolution 5/89, Annex 2 of the International Undertaking on Plant Genetic Resources.

77 Article 8(j): "Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices".

78 Subregional preparatory meeting: West and Central Africa Report, para 39.

79 Subregional preparatory meeting: South and Southeast Asia and the Pacific Report, para 31; Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, paras 13(b), 14(ix), 14(xii); Country Reports Angola, Zimbabwe, India, the Philippines.

80 Country Report the Philippines. The first mentioned bill is House of Representatives Bill No. 38, 1995, the second is Senate No. 277.

81 Subregional preparatory meeting: West and Central Africa Report, para 39; Indonesia identifies research on on-farm conservation as the foundation on which the development of Farmers' Rights can be built. Country Report Indonesia.

82 Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation(xii).

83 Convention on Biological Diversity, Article 20.

84 For more information, refer to the Secretariat's paper: FAO (1996) *Assembling of data on current expenditures in conservation and utilization of PGRFA.* Information paper presented to the International Technical Conference on Plant Genetic Resources, 17-23 June 1996, Leipzig, Germany. ITCPGR/96/Inf.1.

85 Pardey PG and Alston JM (1995) *Revamping agricultural R&D 2020.* Brief 24, IFPRI.

86 This includes five projects specifically devoted to PGRFA, plus an estimated share (5%) of a number of projects for biological diversity conservation which are likely to contribute to PGRFA conservation.

87 Op. cit., endnote 84.

88 Subregional preparatory meeting: Southern Africa Report, para 12(x); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, para 13(e); Subregional preparatory meeting: Mediterranean Report, para 29.

[89] FAO (1995; 1996) *Revision of the International Undertaking on Plant Genetic Resources. Analysis of some technical, economic and legal aspects for consideration in Stage II*; CPGR-Ex1/94/5Supp., reissued as CPGR/6/95/8 Supp. Swanson T, Cervigni R and Pearce D (1995) *The appropriation of the benefits of plant genetic resources for agriculture: an economic analysis of the alternative mechanism for biodiversity conservation*. Commission on Plant Genetic Resources background Paper No. 1. FAO, Rome.

[90] Programme area 14G.

[91] Resolution 3 of the Nairobi Final Act, see footnote 7.

[92] Decision II/15 of the Second Session of the Conference of the Parties to the Convention on Biological Diversity, 6-17 November 1995, Jakarta, Indonesia.

[93] Most Subregional preparatory meetings and most Country Reports including those of: Angola, Canada, Colombia, Cuba, Denmark, Eritrea, Ethiopia, France, Germany, Ghana, Ireland, Italy, Republic of Korea, Morocco, Papua New Guinea, Spain, the Sudan, United Republic of Tanzania, Venezuela, Yemen, Yugoslavia, Zaire.

[94] FAO Conference Resolution 3/91, and FAO (1991) *Report of the Commission on Plant Genetic Resources, Fourth Session, 15-19 April 1991*.

[95] Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, paras 13(b), 14(ix), 14(xii).

[96] Subregional preparatory meeting: Southern Africa Report, para 12(ix); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, recommendation(xii).

[97] Report of the Tenth Session of the Working Group of the Commission on Plant Genetic Resources, CPGR-6/95/REP, Appendix C, particularly paragraphs 23-26; Report of the Sixth Session of the Commission on Plant Genetic Resources, CPGR-6/95/REP, Appendix K. See also Esquinas-Alcazar JE (1996) *The realization of Farmers' Rights*: Paper presented at the Technical Consultation on an Implementation Framework for Farmers' Rights, 15-18 January 1995, Madras, India.

[98] Ibid.

[99] I*nter alia:* Subregional preparatory meeting: Southern Africa Report, para 12(xi); Subregional preparatory meeting: East Africa and the Indian Ocean Islands Report, paras 13(b), 14(ix), 14(xii); Subregional preparatory meeting: West and Central Africa Report, para 39; Subregional preparatory meeting: South and Southeast Asia and the Pacific Report, recommendation 31.

[100] Note however that FAO Conference Resolution 5/89 states that Farmers' Rights are "vested in the international community".

[101] Genetic Resources Action International proposes a biological diversity community rights regime based on the principles of local heritage, tenurial rights and communal ownership over resources. GRAIN (1995) *Towards a biodiversity community rights regime*. Seedling Volume 12, No. 3 p. 2, October 1995, Barcelona, Spain.

[102] Resolution FAO/CL 111/1. Report of the Council of FAO, Hundred-and-eleventh Session, Rome, November 1996, FAO CL 111/REP.

[103] Decision CBD/CoP III/11. Report of the Third Meeting of the Conference of the Parties to the Convention on Biological Diversity, November 1996, Buenos Aires, UNEP/CBD/COP/3/38.

[104] WFS Commitment 3; Objective 3.2(I). Appendix to the *Report of the World Food Summit*, 13-17 November 1996, FAO WFS 96/REP.

[105] FAO (1996) Global Plan of Action for the Conservation and Sustainable Utilization of PGRFA, as adopted by the International Technical Conference, Leipzig, Germany, June 1996, ITCPGR/96/5.0.

# ANNEX 1-1
# Methods for Analysing and Assessing Genetic Diversity, Erosion and Vulnerability

## A1-1.1 INTRODUCTION

Genetic diversity comprises the total genetic variation present in a population or species. It is this variation which determines how well a population or species can adapt to environmental challenges, such as new crop pests and diseases, drought, etc. Long-term food security is continually threatened by such challenges and by growing human populations. Agriculturists — and plant breeders in particular — depend on the variation within the gene pool of crop species and their wild relatives, both to overcome environmental threats and to increase crop yields.

Diversity can be analysed at the intra- and inter-specific levels; both of these are crucial to plant genetic resources for food and agriculture (PGRFA), in terms of the available genetic diversity in the primary, secondary or tertiary gene pools. Diversity can also be studied at other organizational levels, from ecosystems through to cellular, sub-cellular and molecular levels. The level of analysis will depend on the user's purpose in undertaking the study. For example, a genebank curator may wish to conserve a rare agronomic trait in a distantly related wild relative, while a plant breeder may be interested in a gene complex from a landrace. Farmers, gardeners and NGOs may be interested in conserving "heirloom" varieties for their colour, texture or cultural significance to a region.

Whatever the level of analysis, the purpose is to detect and quantify variation. The important questions are: Which traits should be measured? What kind of variation is present and how much? and Where is it to be found?

Measurements can be made of the extent of variation (*polymorphism)* of clear-cut *qualitative traits*. These include colour, morphology and enzyme variants, which are traits typical of *characterization data*. In this case, diversity measurements reflect the extent of polymorphism present; the more polymorphic traits/genes that are available and the more gene variants or alleles in each, the more genotypes it is possible to identify and, hence, the greater the discriminatory power.

Accessions may differ in the frequencies of alleles for a trait. Very often these traits are not agronomically relevant, but are chosen as *marker genes* to monitor the extent of diversity. They may, however, be genetically linked to agronomic traits.

More technical methods are usually needed to analyse genetically complex *quantitative traits* that vary gradually or continuously over a scale. These include agronomic traits such as yield capacity or plant height which are more typical of *evaluation data* in the PGRFA context. Accessions may differ in mean value as well as distribution (variance) within a trait and such traits are greatly influenced by the effect of the environment.

Most conservation theory and practice tend to favour using qualitative traits in the analysis of diversity. Breeders, however, tend to pursue quantitative traits in defining their "breeding goals". The relationship between the conservers and users of PGRFA is a key issue in the management of PGRFA.

In the development of conservation strategies, the analysis of genetic diversity at local and national levels is necessary:

- to guide collecting priorities or designation of *in situ* or on-farm conservation areas;
- to monitor genetic erosion;
- to determine the evolutionary history of crops to inform breeding strategies;
- to guide the management of germplasm collections, including the establishment of core collections;
- to guide utilization of germplasm, for example in plant breeding;
- to monitor potential genetic vulnerability, and guide the deployment of resistance genes;
- to monitor the transfer of genetic resources.

## A1-1.2 METHODS FOR ASSESSING OR ANALYSING GENETIC DIVERSITY

A number of methods can be used to analyse genetic variation. Since each of these provides different types of information, the choice of method depends upon the information required as well as the resources and technological infrastructure available.

### A1-1.2.1 Taxonomic analysis of interspecies diversity

Taxonomic expertise is essential for surveying the diversity of species in a region and for the establishment of species inventories which map their geographic range. For many underutilized crops and wild food plants, such surveys are an essential prerequisite to further studies of the diversity within particular species.[1] There is a need to increase scientific capacity in the area of taxonomy, particularly in many developing countries.[2] Current initiatives, such as BioNET-International, seek to strengthen the taxonomic capability of developing countries to help inventory their resources effectively.[3]

### A1-1.2.2 Analysis of intra-specific diversity

The comparative study of genetic variation between different individuals or populations is based mostly on methods which use *markers* that vary between the entities analysed. Markers are typically used as tools to characterize PGRFA. These markers can be visible to the naked eye (e.g. some phenotypes) or only observed by technical means (e.g. isozymes, DNA markers). However, there are a number of requirements that apply to all markers. They should: (i) be heritable, (ii) discriminate between the individuals, populations or taxa being examined, (iii) be easy to measure and evaluate, (iv) provide comparable results, and (v) be known to be either neutral or unlinked.[4]

#### Pedigree methods

Intra-specific diversity may be estimated by examining the *pedigrees* of different cultivars. Given certain assumptions, in particular that all parents contribute equally to the progeny, the degree of relatedness between individual cultivars can be estimated. This method of assessing diversity is a very useful characterization parameter that allows estimates of inbreeding or assessments of genetic variability. It is, of course, only possible for cultivars where pedigree records are available. It cannot be used for historically undocumented traditional cultivars such as landraces or for composites (Box A1.1).

**Box A1.1 The International Rice Genealogy Database**

The International Rice Research Institute (IRRI) maintains an International Rice Genealogy Database (IRGDB) on the genetic ancestry of rice varieties and of hybridizations made in national programmes. The records include data on 2,500 IRRI varieties released after the development of IR8, 1,600 varieties released before IR8 and 1,500 varieties used as parents, compiled from 75 countries. There are plans to integrate the IRGDB with the germplasm collection at IRRI, the database of IRRI crosses and the database of the International Network for the Genetic Evaluation of Rice.[5]

### Phenotypic analysis

Phenotypic traits describe the observable characters of an organism. In plants, they include flower colour and growth habit. Phenotypic analysis is easy and inexpensive, but the markers are often insufficiently variable to provide useful results. The *descriptor lists* of the International Plant Genetic Resources Institute (IPGRI) provide detailed information about how to collect phenotypic data for characterization of a wide range of plant genetic resources (Table A1.1).

These are the most common form of PGRFA data available for *ex situ* accessions. They are, however, less frequently used in academic studies since their genetics may be unclear.[6] Q*uantitative agronomic traits* measure the differences between individuals and populations with regard to genetically complex traits such as stress tolerance and yield potential. The diversity of a population with regard to these complex traits can be described by its *genetic variance* and *mean value*. Typically, PGRFA are screened for these traits, selected for relative superiority, and tested for breeding value. The traits detected are useful, but frequently strong environmental influence makes their use difficult as universal classification criteria.

### Molecular methods

Molecular marker techniques have become powerful and accurate tools for the analysis of genetic diversity.[7] A major advantage of molecular and biochemical methods is their genotypic nature which allows them to reflect changes at the DNA level across the entire genome and their general ability to detect more genetic variability. Some molecular markers also make it possible to study chloroplastic and mitochondrial DNA, in addition to nuclear DNA, and hence to permit precise and versatile analyses of genetic variation.

**Table A1.1 Crop species descriptor lists published by IPGRI**

| Crops | | | | |
|---|---|---|---|---|
| Almond | Citrus | Lentil | Pearl millet | Sorghum |
| Apple | Coconut | Lima bean | *Phaseolus acutifolius* | Soybean |
| Apricot | *Colocasia* | Lupin/*Lupinus* | *Phaseolus coccineus* | Strawberry |
| Bambara groundnut | Cotton | Maize | *Phaseolus vulgaris* | Sunflower |
| Banana | Cowpea | Mango | Pigeon pea | Sweet potato |
| Barley | Cultivated potato | *Medicago* (annual) | Pineapple | Tropical fruit |
| Beta | *Echinochloa* millet | Mung bean | Plum | *Vigna acuntifolia* |
| *Brassica* and *Raphanus* | Eggplant | Oat | Potato variety | *Vigna trilobata* |
| *Brassica campestris* L. | Faba bean | Oca | Quinoa | *Vigna mungo* *Vigna radiata* |
| Buckwheat | Finger millet | Oil-palm | Rice | Walnut |
| Cardamom | Forage grass | *Panicum miliaceum* | Rye and triticale | Wheat and *Aegilops* |
| *Capsicum* | Forage legumes | *Panicum sumatrense* | Safflower | White clover |
| Cashew | Grape | Papaya | Sesame | Winged bean |
| Cherry | Groundnut | Peach | *Setaria italica* | *Xanthosoma* |
| Chickpea | Koda millet | Pear | *Setaria pumilia* | Yam |

The technical and practical advantages and disadvantages of some commonly used molecular techniques are summarized in Table A1.2. The choice of technique depends on the question being asked.[8]

Some of the more widely used molecular marker techniques are:

(a) **Isozyme analysis**, which is based on protein polymorphisms between enzymes or seed storage proteins, revolutionized the analysis of genetic diversity when it was introduced 25 years ago[9] and is still widely used today. It remains a relatively inexpensive and reliable technique. Isozyme analysis can typically analyse as many as 20 to 30 loci with up to 5 or 6 variants detected at each locus. Its usefulness has been somewhat limited by its inability to detect polymorphism in the highly developed germplasm of some species (e.g. wheat).

**Table A1.2 Advantages and disadvantages of some currently used methods of measuring genetic variation**

| Method | Variation detected | Sample through-put | Loci analysed per assay | Reproducibility between assays | Type of character analysed | Inheritance of character analysed | Technology level required |
|---|---|---|---|---|---|---|---|
| Morphology | low | high | low no. | medium | phenotypic trait | qualitative / quantitative | low |
| Pedigree analysis | medium | n.a. | n.a. | good | degree of co-ancestry | n.a. | low |
| Isozymes | 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 | high to medium | high | high no. (random) | poor | DNA | dominant | medium |
| DNA sequencing | high | low | low no. (specific) | good | DNA | co-dominant dominant | high |
| Seq tag SSRs | high | high | medium no (specific) | good | DNA | co-dominant | high |
| AFLPs | medium to high | high | high no. (random) | medium | DNA | dominant | high |

**(b) DNA-based techniques** have been developed over the past decade which have definite advantages over both phenotypic and isozymic methods. The new techniques have the potential to screen rapidly dozens or even hundreds of loci with several alleles detected at each locus. However there is a bewildering variety of these techniques (and their acronyms) and new methods are being developed continually. Detailed description of these techniques can be found elsewhere.[10] Briefly, the DNA techniques may be classified into three general types:

**(c) DNA sequencing** is a widely used technique which allows the description of the linear sequence of the four unit molecules (base pairs) composing a piece of DNA.[11] In theory, DNA sequence information provides the "ultimate" environment-independent description of a particular genotype. At present, due to the prohibitive cost of large-scale DNA sequencing, it has mostly been limited to the sequencing of single genes or small regions of chromosomes. However for a few species, such as rice[12] and *Arabidopsis thaliana*,[13] large-scale sequencing of the genome is being performed. Nevertheless, the direct application of this technique is more in the identification of the gene(s) than the genotype, with a very limited possibility to sample many variants for PGRFA characterization.

**(d) Restriction enzyme fragment length polymorphism (RFLP)** techniques are based on cutting DNA with enzymes that only recognize certain specific short sequences of DNA. If two genotypes, which differ in the location of these recognition sequences as a result of their evolutionary history, are separately cut with a particular enzyme, molecules of different sizes can be viewed using a technique called electrophoresis. The number of molecules and their size are then indicators of the genetic difference (polymorphism) between the two genotypes.

**(e) Polymerase chain reaction (PCR)** techniques are simpler to use and less labour-intensive than RFLPs. These techniques allow the amplification of fragments of DNA - which can be separated easily by electrophoresis - to view genetic differences between genotypes. There are a wide variety of PCR-based techniques, including:

- The **random amplified polymorphic DNA (RAPD)**[14] technique which can be used to generate “DNA fingerprints”. It is much used, particularly where relevant DNA sequence information is not available (or where funds/ resources are limited). However, reproducibility of results between laboratories is a problem.
- **Microsatellite analysis** is increasingly used where specific DNA sequence information (and the necessary resources) are available to analyse specific and highly polymorphic loci (called microsatellites) across the genome.[15]
- The more recent **AFLP (Amplified Fragment Length Polymorphism)**[16] technique also detects high levels of polymorphism. It is considered promising for PGRFA applications but has as yet not been widely tested.

Newer molecular techniques that can be automated for the high through-put of samples - necessary for much plant genetic resources analysis - are now becoming commercially available as a result of technology spillovers from the Human Genome Project.[17] This project is currently costing US ò200 million per year in the United States alone. The total cost to provide a complete human genome sequence is expected to be about ò1,000 million.[18] At present, the best semi-automated technology can genotype over 100,000 samples, using approximately 250 marker loci, in less than six months.[19] Current research into the development of third-generation “DNA chip” technology holds much promise for further increasing the automated through-put of samples.[20]

### A1-1.2.3 Use of indigenous and traditional knowledge for analysing useful diversity

It is now generally recognized that indigenous and local knowledge can be a crucial factor in agricultural research, extension and sustainable development.[21] Clearly, indigenous knowledge is of great use in the search for new crops or new useful characteristics in wild or cultivated plants.[22] Collecting local and indigenous knowledge associated with plant genetic resources also provides opportunities for information exchange, as farmers can inform breeding programmes of their crop needs.[23] The role of indigenous knowledge in PGRFA is highlighted by studies on bean landraces in Malawi.[24] The studies demonstrated that women are the principal cultivators of beans, and have detailed knowledge of their names and properties. Previous studies had neglected the gender dimension and arrived at completely different assessments of the diversity of the bean landraces.

Choosing the most appropriate technique for measuring diversity can be a challenge due to the number of available choices. The temptation may be high to rely on the most frequently used or the newest techniques, without adequately evaluating the range of options available or the resources required to support them. The appropriateness of different molecular techniques for different applications is being analysed by projects such as the European Union study on molecular genetic screening tools which involves 45 collaborating research institutions.[25] Technical relevance aside, cost considerations must also influence the choice of technologies, particularly for transfer to resource-poor countries. Where resource and cost considerations are restrictive, it must be remembered that the taxonomic, phenotypic and indigenous knowledge-based methods are inexpensive and still provide highly useful information about genetic diversity. In fact, the major limiting factor for the use of these techniques is human resources.

### A1-1.2.4 Transfer of molecular marker technologies to developing countries

There is currently no shortage of techniques for measuring genetic diversity, and newer and more accurate methods are being developed all the time. The widespread use of more refined molecular methods is severely limited by their costs which differ significantly among methods (Box A1.2). Phenotypic methods are inexpensive, requiring only trained personnel. Isozymic methods provide useful information and are relatively inexpensive. RFLPs, microsatellites and AFLPs are currently expensive due to the laboratory facilities and running costs required. Most PCR-based methods demand similar equipment. The running costs of some of the simpler techniques (RAPDs) are less - in some instances, they are comparable to isozyme analysis. However, the reality is that even the costs of the latter are prohibitive in many underfunded PGRFA programmes, and especially so in developing countries.

**Box A1.2 Relative costs of using molecular markers**

A recent detailed cost analysis of RFLPs vs. RAPDs revealed running costs (excluding investments and labour) per data point ranging from US $0.14 to $0.76 for RFLPs, and from $0.18 to $1.30 for RAPDs. However, due to 6-fold higher prices for radioactive labelling chemicals in Mexico, RFLP costs could reach US $1.72, rendering the use of this protocol prohibitive in Mexico and most likely in many other parts of the developing world.[26] It is worth considering that as newer DNA technologies are developed, the relative cost of using the technologies continues to decrease. It is therefore unwise to state definitively that one technique is more appropriate than another on the basis of current cost. Experience suggests that current methods will be superseded by newer and better techniques providing more favourable cost to unit biological information ratios. For example, the Advanced Technology Program of the United States National Institute for Standards and Technology aims to deliver automated, high through-put and user-friendly molecular diagnostic techniques at 0.1 to 0.01% of the current price of existing molecular marker systems.[27]

Not withstanding the future potential for lowered costs, there are serious obstacles to the transfer of many current biotechnologies to developing countries. Most of the current DNA-based methods require extensive technical and infrastructural support services which are not available in many developing countries. For instance, most molecular biology work requires a critical mass of high technology equipment. Replacement parts and technical back-up are not readily available in most developing countries.

Molecular biology work requires a supply of consumable materials and relies heavily on the use of enzymes and other biological products which perish rapidly if not properly handled and stored. Most of these products must be imported from developed countries. For instance, many enzymes must be constantly refrigerated while *en route* from the manufacturer to the laboratory. Also, much molecular biology work requires the use of radioactive materials which must be delivered before their short half-lives expire. Rapid delivery systems are either not available or prohibitively expensive in many developing countries. Other problems are associated with the unreliability of essential services such as power and water supplies in many developing countries.

Many developing countries lack sufficient numbers of trained scientists with access to up-to-date scientific literature and with the resources to interact and exchange ideas among themselves and with the international scientific community.[28] Needless to say, the success of a country's plant research efforts will be a function of its ability to draw on sufficient technical expertise and support.[29]

Plant samples are generally easily transportable to centralized laboratories. In this respect, the establishment of regional centres of excellence for analysing the genetic diversity of prioritized PGRFA of importance to food security in particular regions would be a rational approach to take.

## A1-1.3 SOME USEFUL APPLICATIONS OF METHODS FOR ASSESSING GENETIC DIVERSITY

Studies using protein and DNA markers have put "flesh on the bones" of population genetics. These studies, together with phenotypic and socio-cultural information, will help to increase understanding of the dynamics of plant population genetics, whether on the farm or in the wild. Information on gene flow, mating between plants and selection pressures will help us understand how genetic diversity is generated, structured and lost. This, in turn, will be useful for plant breeding as well as PGRFA conservation. What follows are examples of the types of useful information that can be provided by genetic diversity analysis.

### A1-1.3.1 Guiding collecting priorities or designation of *in situ* or on-farm conservation areas

The potentially wide geographic distribution of genetic variation poses a problem for the easy conservation of the maximum genetic diversity for any plant species, whether as *ex situ*, *in situ* or on-farm collections. This is because it is not easy to determine which regions are "hot spots" of genetic or agronomic trait diversity and thus require more intensive conservation efforts. It has been proposed that conservation strategies should therefore take into account the frequency with which particular alleles or phenotypes are found over the geographical range of the species[30] (Table A1.3). Differences between populations within a species in the total amount of genetic diversity appear to be greater in self pollinated species than in cross-pollinated species.[31] Assessments of the extent of

**Table A1.3 Different conservation strategies for different frequencies of alleles or phenotypes**

| Allele frequency | Allele distribution | Collecting strategy | Populations to sample | Resources required |
|---|---|---|---|---|
| Common | Widely distributed | Random | Few | Low |
| Common | Locally distributed | Targeted | Dependent on strategy | Dependent on strategy |
| Rare | Widely distributed | Random | Many | High |
| Rare | Locally distribution | Targeted | Dependent on strategy | Very high |

*Source*: Adapted from Marshall and Brown (1975) distribution of genetic diversity will be particularly valuable in efforts to develop *in situ* conservation strategies for germplasm that is not suited to long-term, inactive storage, as is the case for the wild relatives of cassava.[32]

#### Geographical Information System

The use of genetic diversity assessments in conjunction with agro-ecological data arranged in Geographic Information Systems (GIS) is now seen as an excellent means to help determine efficient sampling strategies for collection either within or across ecological zones.[33] The International Centre for Tropical Agriculture (CIAT) and IRRI are currently using GIS as a tool for exploring the geographical distribution and potential agronomic utility of genetic diversity in wild relatives. Passport information on over 1,000 CIAT accessions of wild *Phaseolus vulgaris* has been combined with other agro-ecological information to develop predictive models for locating agronomically useful germplasm in regions where no collecting has previously been undertaken. While this approach will not indicate genetic variation itself, which must be determined independently, it can indicate the types of genetic variation which may be associated with certain combinations of environmental or social parameters.[34] In the context of programmes to rehabilitate genetic diversity in farming systems disrupted by war, civil strife or other major changes, GIS techniques are being used to identify areas of similar agro-ecological conditions, where local varieties with the required characteristics for transfer to the affected areas are likely to be found.[35]

### A1-1.3.2 Use of genetic diversity assessments to monitor genetic erosion

Genetic erosion is the loss of genetic diversity, generally as a result of social, economic and agricultural changes. The replacement of a farmer's unique variety or landrace by a high-yielding type may cause the loss of intra-species genetic diversity on two levels: by reducing the *genotypic* diversity and/or by reducing the *allelic* diversity within the cultivated crop.

Most indicators of genetic erosion are limited to noting changes at the species or varietal level. Some potential indicators of genetic erosion of landraces include:

**Occurrence of landraces**

- Number of landraces (or "farmers' varieties")
- Vernacular names of landraces
- Main distinctive morphological or agronomic traits

- Changes in the area under cultivation
- Changes in agronomic practices

**Population diversity of landraces**

- Estimates of phenotypic diversity
- Estimates of population size
- Estimates of extent of distribution in target area

**Modern varieties**

- Area under cultivation relative to landraces or primitive cultivars
- Seed source and distribution mechanisms
- Promotion of new agronomic practices and varieties
- Reasons for introduction of new varieties

As genetic diversity in traditional agricultural systems is connected with the existence of different human cultures, the status of these cultures can provide useful information about PGRFA. The demure of distinct languages, for example, may be an indicator of loss of genetic diversity generated and nurtured by those language and culture groups.

Molecular marker studies have been used to investigate the level of gene flow between wild relatives and their associated crops where these grow in close proximity. Using these techniques, gene flow has been demonstrated, in both directions, between cultivated maize and its wild *Teosinte* relatives in Mexico,[36] while very little gene flow has been observed between cultivated pearl millet and its wild relative in the Sahel.[37] If modern varieties are to be grown in the centres of diversity of the world's staple crops, an understanding of the rates of gene flow is essential for developing rational *in situ* and on-farm conservation strategies to avoid erosion of both wild and domesticated crop resources.

## A1-1.3.3 Determining the evolutionary history of crops

Knowledge of the evolutionary history of crops is highly useful for developing strategies for conserving and using genetic resources. Some of this information may be obtained through molecular marker studies associated with genetic mapping projects. For instance, it is now considered likely that a small number of genetic loci were selected by the earliest farmers in the process of domesticating maize[38] and that similar genetic loci were involved in the independent domestication of sorghum and rice.[39] This suggests that the earliest farmers were selecting large-seeded, non-shattering cereal types from the small-grained shattering wild cereals. The selection they may have imposed involved similar regions of the genome.

Traditionally, wild ancestors have been identified on the basis of morphological similarity between the crop and a wild relative. More recently molecular studies have been used to confirm the identity of the ancestral wild relative. *Teosinte* has been confirmed as the actual and immediate progenitor of maize through the use of molecular techniques,[40] and the closest wild relatives of at least another 13 crop species[41] have been identified or confirmed.[42] Molecular markers can also be used to identify the geographic areas in which domestication most likely occurred and what parts of the genome were modified in the process. Such analyzes can be of use in designing sampling strategies for conservation or for choices of germplasm for breeding purposes.

### A1-1.3.4 Use of genetic diversity assessments to guide the management of germplasm collections

Characterization data are the principal management tool of the genebank curator. These data are used to discriminate between accessions, to detect redundancies, to establish core collections and to monitor genetic changes during maintenance. For rational and effective management of germplasm collections, it is preferable that curators address some specific issues (Table A1.4). Marker traits are preferred for this work due to their versatility and reproducibility. Ideally they should (a) be applicable - within economic limits - to all relevant accessions and (b) represent the genetic variation across the whole genome. This

**Table A1.4 Some major issues and questions of interest to genebank curators**

| Issue | Question |
|---|---|
| Identity | Is the entry in the collection catalogued correctly and true to type? |
| Relatedness | What is the degree of similarity between individual genotypes in an accession or among accessions in the collection? |
| Structure | What is the amount of genetic variation present and its distribution among accessions and individual genotypes? |
| Location | What is the location of a desired gene or gene complex in an accession and also the physical site of a desired DNA sequence on a particular chromosome in an individual plant? |

*Source:* Kresovich et al. (1995)[43]

ideal is currently not attainable due to financial, technical and human resource constraints. As a result, few PGR collections have even been fully characterized for common morphological descriptors, although characterization data based on these are relatively inexpensive to develop and assemble for the management of germplasm collections. This lack of characterization is one of the constraints on the wider use of germplasm collections by breeders and others.

The use of protein or DNA polymorphisms to characterize entire collections is currently considered too expensive for routine management of accessions in most genebanks, as well as in much public and private plant breeding (except in some cases of marker-assisted selection). Protein and DNA markers may be useful, however, for "pilot" surveys of subsections of collections. Since many more loci may be characterized, the genome may be better represented, and some level of resolution of the genetic structure of a collection may be obtained.

The increased understanding of plant populations made possible through marker characterization will have great repercussions for both PGRFA conservation and plant breeding. For example, the use of these methods has helped to explain the fundamental differences in population structure between inbreeding and outbreeding species.[44] Whereas the former tend to be differentiated into "patchy" subpopulations, the latter tend to be more continuous in structure, with the bulk of the total variation present in any local population. Such knowledge is essential to proper sampling and conservation of PGRFA. In addition, such questions as the population sizes necessary for conservation, estimation of outcrossing rates or establishment of optimum regeneration protocols may now be addressed.

Where feasible, genetic diversity analysis can be used to determine the genetic relatedness of different accessions in *ex situ* collections. Such information can inform the relative prioritization of accessions and enable genebank managers to develop strategies based on the conservation of the maximum genetic diversity of the crop species. Gaps can be identified in the collection to determine whether further collecting is needed. The combination of genetic diversity information with available data on the distribution of agronomically useful traits across the collection will help to guide the development of core collections for particular species.

### A1-1.3.5 Genetic diversity analysis and germplasm utilization

The use of qualitative markers for germplasm improvement is often limited because of the lack of direct relationship between such markers and many agronomically significant traits. The same agronomic trait can often be conferred by different genotypes and it is therefore often difficult to equate trait with genotype. In fact, different types of markers and traits frequently reveal different patterns of distribution. For example, in a study of 1,118 barleys from an international collection, while morphological markers suggested that the maximum diversity was to be found in the Vavilovian centres, the maximum diversity for agronomic traits or protein markers was not located in the same geographical area.[45] A similar discrepancy was noted in sorghum, but this was later resolved by studies using a large set of RFLP markers. The basic morphologically based grouping of sorghums was confirmed, but in a much more fine-tuned pattern.[46] Genetic diversity analyses have also shown that some crops which demonstrate much phenotypic diversity have relatively narrow primary and cultivated gene pools. This is the case for tomato, pepper, soybean, melon and peanut, among others. It is believed that this may be the result of severe genetic bottlenecking either during the domestication process or later in the crop's evolutionary history.[47]

This lack of correlation between phenotypic and genetic diversity presents major problems for the conservation of agronomically useful genetic diversity. While the use of genetic markers does reveal patterns of broad evolutionary trends, these patterns may not necessarily be related to the occurrence or evolution of those useful genes or genome regions resulting from selection pressures imposed by farmers, diseases, pests and abiotic environments. The distribution of such genes may be related more to the distribution of selection pressures than to the line of descent from an ancestral stock.[48] Indeed the patterns of useful phenotypes selected by farmers demonstrate the impact of human selection in traits that are not "neutral" to their needs.[49]

Genetic maps, which are densely covered by the same genetic markers used to determine levels of genetic diversity, will be invaluable for increasing the use of plant genetic resources of some crops. The association of DNA markers with useful agronomic traits can allow the rapid marker-assisted introgression of agronomic traits into modern cultivars.

Recent efforts to map genes in cereal species as seemingly diverse as barley and rice[50] or sorghum, maize and rice[51] have concluded that the chromosome structure and order of the different species are so similar that they can be fused into one genetic map. This will enable researchers to use the same genetic markers from the best mapped species (e.g. rice) for genetic analysis in less well mapped though seemingly unrelated species.

Comparative mapping will allow a significant increase in the use of crop gene pools and also help to identify those common genetic loci across the crop species which are of most interest to agriculture.

### A1-1.3.6 Use of genetic diversity assessments to monitor genetic vulnerability

To date, few systematic attempts have been made to monitor genetic vulnerability for the purposes of agricultural management. However, it is technically feasible to develop risk management models to assess levels of genetic vulnerability - and hence the risk of production losses - by looking at variables such as:

- the relative areas sown to different cultivars;
- the extent of genetic relatedness between the different cultivars.

The extent of genetic diversity within the cultivated gene pool of modern varieties can also be determined from pedigree analysis of the most widely planted cultivars. Pedigrees, however, are not always available, even for major cultivars.

In some countries, such as Canada or Norway, the open availability of pedigrees is encouraged by plant breeders' rights (PBR) laws, whereas in others they are kept as trade secrets. Pedigree analysis can provide an indication of the potential long-term genetic vulnerability of the cultivated crop and act as an impetus for incorporating new genetic material to broaden the genetic base of the crop. The availability of a complete pedigree, perhaps after a limited "grace period", could help agriculturists in making agronomic recommendations on breeding and on cultivar deployment in production systems.

In 1977, a predictive model was developed for assessing the genetic vulnerability of the dry bean crop to disease epidemics in nine states of the United States.[52] A genetic distance index, based on 36 chemical and agronomic traits, was calculated for each of the 27 most popular dry bean cultivars, to assess the homogeneity of beans grown in each production region. By combining these estimates of genetic similarity with the area covered by each cultivar, a homogeneity index was calculated for each bean-producing state.

The model predicted that Colorado and Wyoming were the two states at greatest risk of a pathogen epidemic. In 1981-1982 Colorado and Wyoming suffered an epidemic of rust (*Uromyces appendiculatus*) causing damage of US ò15-20 million. Since 1983, major breeding efforts by United States scientists on rust resistance in dry beans have produced rust-resistant cultivars based on germplasm derived from the CIAT genebank in Colombia.[53]

### A1-1.3.7 Use of genetic diversity assessments to monitor the transfer of genetic resources

The reaffirmation of national sovereignty over plant genetic resources and the increasing application of intellectual property rights to plants and plant varieties has led to a growing interest in developing mechanisms for apportioning the benefits derived from the use of PGRFA. The design and implementation of such mechanisms would ideally require that the identity and origin of material be established. This has resulted in great interest being shown recently in the use of molecular markers to trace genetic material. For example, because a number of powerful, modern genetic "fingerprinting" techniques exist, and have been successfully applied in forensic analysis,[54] it is often assumed that similar techniques can be used to identify plant germplasm or genes, and to trace genes back from a modern variety to their original geographical origins.

In this case, distinction must be made between an original accession, the population from which it was sampled, a single genotype from the accession and a particular gene from the accession. Genetic fingerprinting and related techniques can help to analyse the genotype and the particular combination of genes and alleles contained in an accession. Diverse populations, on the other hand, can only be described in terms of genotypes and allele frequencies.

Molecular markers are now being used for the protection of modern varieties in the context of Plant Breeders' Rights.[55] They can reveal, for instance, whether new varieties registering for PBR protection comply to the distinct, uniform and stable criteria of UPOV[56] (see Chapter Seven). Further refinement of molecular techniques will theoretically improve the level of resolution and allow researchers to distinguish even between closely related cultivars. Indeed, recent research demonstrated that oilseed rape varieties previously considered to be uniform under the UPOV DUS criteria displayed some genetic heterogeneity when analysed by RAPD markers. In the future, it is possible that molecular markers will be used to determine the genetic distance between varieties. This may allow the identification of essentially derived varieties (e.g. varieties with single gene changes introduced by backcrossing or genetic transformation) as defined by the 1991 UPOV Convention.[57] Some companies now routinely run genetic profiles on more than 100 loci for their maize inbreds, for instance, to back up possible legal claims if other varieties are essentially derived or "too similar".

Modern molecular techniques may, under certain conditions, prove to be useful in determining the probable identity and origin of landraces, genotypes and genes. However, it is unlikely that these techniques can be of routine and practical use in the context of agreements for access to plant genetic resources for food and agriculture. Among the major reasons that would make their use in such a context difficult are the following:

- Great variability is inherent in most landraces and populations. This variability becomes an obstacle to identification, complicated by the fact that very few individuals can usually be sampled in identification studies, because of the costs involved (particularly in sequencing and RFLPs).
- Genes do not respect national borders; the same kind of genotypes, or the same gene, may be found in a number of countries, especially if they are neighbours. Even if the probable origin of a genotype can be suggested, it would still be difficult to prove legal identity. Even where biological origin can be proved (which is exceptional), it may not necessarily serve the country or region of origin, since this may not be the *provider of the accession*, to which the Convention on Biological Diversity confers specific rights.
- Methodological imprecision means that different technologies may give different conclusions regarding the identity and possible origin of the same genetic material, and hence give rise to disputes.[58] Moreover, genetic engineering could be used deliberately to modify the gene sequence, and blur its identity.
- Tracing genetic material may be even more problematic when the material has been introduced into the complex pedigrees of a plant breeding programme. Even though modern techniques may reveal some "residual" donor DNA, the results will inevitably be equivocal. The presence of genes from nine landraces and one wild species in the rice cultivar IR72[59] illustrates the problem of tracing the origin of genes from a particular genotype in its pedigree, let alone of attempting to assign a marginal value to its contribution to a commercial variety.
- There is a significant difference between diagnostics and forensics. For legal purposes, it will be difficult to prove beyond a reasonable doubt that a particular accession, gene complex or gene originated in a particular geographic location or country, even with modern molecular markers. In addition, in the domestication studies discussed earlier, geographical origins are assigned with a degree of probability only. It should be noted that the origin of a particular variety, landrace, genotype or gene is not necessarily the same as the centre of origin, centre of diversity or centre of domestication of the species. It will therefore be extremely difficult to *prove* the identity and origin of unknown genetic material.[60]

Modern methods of genetic analysis are continually improving the ability to describe genotypes. In certain cases, it is possible to conclude or claim that two genotypes are genetically identical, and to point to the genetic similarity or distance between genetic resources with the same or different geographical origins. On this basis, it may be possible to assign a probable geographical origin to a particular accession. This, however, will rarely specify a country, much less a farming community. It will usually be impossible to prove that the genotype or gene does not also occur elsewhere, particularly in neighbouring countries and, in many cases, the country of origin may not be the provider of the accession. Moreover, the material may already exist elsewhere through previous exchange of germplasm.

Once the genotype has been included in a breeding programme, only the known and identifiable genes it contains can be traced, through either actual DNA sequences or tightly linked DNA markers. However, it is at present not feasible to consider determining the DNA sequence of most genes of value to plant breeding. Using markers may be simpler, but both methods demand very substantial and expensive research investments.

Similar methods may theoretically be used to distinguish varieties protected by Plant Breeders' Rights, and accessions from landraces and associated wild and weedy species. However, the high variability and segregation of landraces and wild relatives over time point to a fundamental difference from protected varieties under the distinct, uniform, and stable (DUS) criteria. This is an essential distinction, which makes it unlikely that existing PBRs can be used successfully to define and enforce rights over traditional varieties and related wild material collected from agricultural ecosystems created and maintained by farmers.

■

## Annex 1-1 endnotes

1 Prance GT (1995) Systematics, conservation and sustainable development. *Biodiversity and Conservation*, 4:490-500.

2 Eshbaugh WH (1995) Systematics Agenda 2000: a historical perspective. *Biodiversity and Conservation*, 4:455-462; Mc Neely JA (1995) Keep all the pieces: Systematics 2000 and world conservation. *Biodiversity and Conservation,* 4: 510-519.

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

4 Hillis DM and Moritz C (1990) *Molecular systematics*, 1st edition. Sinauer Associates, Inc., Sunderland, Massachusetts, USA, 588 pp.

5 Cabanilla VR, Jackson MT and Hargrove TR (1993) Tracing the ancestry of rice varieties. *Volume of Abstracts*, Birmingham, England, p. 112, 17th International Congress of Genetics, 15-21 August 1993.

6 It should be noted that all the diversity data studied by Darwin or Vavilov were of this type, so very important conclusions have been reached from the use of such markers.

7 Avise JC (1994) *Molecular markers, natural history and evolution,* 1st edition. Chapman & Hall, New York, 511 pp.

8 Karp A and Edwards KJ (1995) Molecular techniques in the analysis of the extent and distribution of genetic diversity. IPGRI workshop, Rome.

9 Brown AHD and Clegg MT (1983) Isozyme assessment of plant genetic resources. *Current Topics in Biological and Medical Research,* 11:285-295.

10 Westman AL and Kresovich S (in press) Use of molecular-marker techniques for description of plant genetic variation. Commonwealth Agricultural Bureau (CAB), London.

11 The linear sequence of the four base pairs provides the primary information content of DNA whether as genes encoding proteins or otherwise. The four base pairs of DNA are molecules called Adenine (A), Guanine(G), Cytosine (C) and Thymine (T). For example, the linear sequence of a randomly chosen 20 base pair fragment of DNA might consist of AGCCTGATGTTGCAATGCTG and, depending on its genetic context and information content, might provide essential functions for a particular organism. To illustrate the huge information content of most higher organisms, the maize genome contains an estimated 5.4 x $10^9$ base pairs while the human genome contains an estimated 3.3 x $10^9$ base pairs.

12 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.

13 The entire genome of the model plant *Arabidopsis thaliana* is expected to be fully sequenced by an international team of laboratories by 2004. A major cost-benefit reason for choosing to sequence this model non-agronomic plant was its small genome size ( V X 10 x). It is expected that the identification and functional characterization of many of its genes will facilitate the identification of their

> agronomically useful counterparts in many crop plants. Dennis E (1995) *Multinational Coordinated* Arabidopsis thaliana *Genome Research Project*. National Science Foundation, Washington, D.C.

14 Tingey SV and Del Tufo JP (1993) Genetic analysis with RAPD markers. *Plant Physiology,* 101:349-352.

15 See e.g. Saghai-Maroof MA, Biyashev RM, Yang GP, Zhang Q and Allard RW (1993) Extraordinarily polymorphic microsatellite DNA in barley: Species, diversity, chromosomal locations and population dynamics. *Proceedings of the National Academy of Science* (USA), 91:5466-5490; Zhang Q, Gao YJ, Saghai-Maroof MA, Yang SH and Li XJ (1995) Molecular divergence and hybrid performance in rice. *Molecular Breeding,* 1:133-142.

16 Keygene NY (1991) Selective restriction fragment amplification: a general method for DNA fingerprinting. European Patent # EP534858 (24/9/91).

17 Collins F and Galas D (1993) A new five-year plan for the United States Human Genome Project. *Science,* 262:43-46.

18 Olson MV (1995) A time to sequence. *Science,* 270:394-396.

19 Reed PW, Davies JL, Copeman JB, Bennett ST, Palmer SM, Pritchard LE, Gough SCL, Kawaguchi Y, Cordell HJ, Balfour KM, Jenkins SC, Powell EE, Vignal A and Todd JA (1994) Chromosome-specific microsatellite sets for fluorescence-based, semi-automated genome mapping. *Nature Genetics*, 7:390-395.

20 Lipshutz RJ, Morris D, Chee M, Hubbell E, Kozal MJ, Shah N, Shen N, Yang R and Fodor SPA (1995) Using oligonucleotide probe arrays to access genetic diversity. *Biotechniques*, 19:442-447; Advanced Technology Program (1995) *Tools for DNA diagnostics White Paper*. National Institute of Standards and Technology, Gaithersburg, Maryland, USA, 11 pp.

21 Warren DM, Slikkerveer LJ and Oguntunji Titilola S (1994) (eds.) *Indigenous knowledge systems: the cultural dimensions of development*. Kegan Paul International, London.

22 Barrau JF (1989) The possible contribution of ethnobotany to the search for new crops for food and industry. In Wickens GE, Haq N and Day P (eds.) *New crops for food and industry*, p. 378-390. Chapman and Hall, London.

23 Guarino L (1995) Secondary sources on cultures and indigenous knowledge systems. In Guarino L, Rao VR and Reid R (eds.) *Collecting plant genetic diversity: technical guidelines*, p. 195-228. CAB, London.

24 Ferguson AE (1992) Differences among women farmers: implications for African agricultural research programmes. *Proceedings of the Workshop on Social Science Research and the Crops*, 9-11 June 1992, Cornahan Conference Centre, University of Kentucky, USA.

25 *Molecular Screening News*, No. 1, August 1993, p. 1-5.

26 Ragot M and Hoisington DA (1993) Molecular markers for plant breeding: comparisons of RFLP and RAPD genotyping costs. *Theoretical and Applied Genetics*, 86: 975-984.

27 See Advanced Technology Program op. cit., endnote 20.

28 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.

[29] Komen J and Persley G (1993) Agricultural biotechnology in developing countries: a cross-country review. Intermediary Biotechnology Service Research Report 2, ISNAR, The Hague, 45 pp.

[30] Marshall DR and Brown AHD (1975) Optimum sampling strategies in genetic conservation. In Frankel OH and Hawkes JG (eds.) *Genetic resources for today and tomorrow*. Cambridge University Press, Cambridge, UK.

[31] Schoen DJ and Brown AHD (1991) Intraspecific variation inpopulation gene diversity and effective population size correlates with the mating system. *Proceedings of the National Academy of Science USA,* 88:4494-97.

[32] 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.

[33] Guarino L (1995) Geographic information systems and remote sensing for plant germplasm collectors. In Guarino L, Rao VR and Reid R (eds.) *Collecting plant genetic diversity: technical guidelines*, p. 315-328. CAB, London.

[34] Op. cit., endnote 32.

[35] ASARECA (1996). *Seeds for Hope II: food security through seed security*. Proceedings of a Consultative Workshop for the Greater Horn of Africa. 6-7 March 1996, Entebbe, Uganda.

[36] Doebley JF, Goodman MM and Stuber CW (1984) Isoenzymatic variation in *Zea* (Graminae). *Systematic Botany*, 9:203-218.

[37] 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.

[38] Doebley J (1992) Mapping the genes that made maize. *Trends in Genetics*, 8:302-307.

[39] 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.

[40] Op. cit., endnote 36.

[41] Avocado, barley, common bean, lentil, lettuce, maize, pea, peanut, pearl millet, pepper, rice, sorghum, soybean and tomato.

[42] 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*, p. 127-146. John Wiley & Sons, Chichester, UK.

[43] 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.

[44] Hamrick JL and Godt MJ (1990) Allozyme diversity in plant species. In Brown AHD, Clegg MT, Kahler AL, Weir BS (Eds.) Plant population genetics, breeding and genetic resources, p. 43-63. Sinauer, Massachusetts.

[45] Cross RJ (1994) Geographical trends within a diverse spring barley collection as identified by agro/morphological and electrophoretic data. *Theoretical and Applied Genetics*, 88:597-603.

[46] Deu M, Hamon P, Chantereau J, Dufour P, D'hont A, Lanaud C (1995) Mitochondrial DNA diversity in wild and cultivated sorghum genome. *Theoretical and Applied Genetics, 38:635-645.*

[47] Clegg MT, Epperson BK and Brown AHD (1992) Genetic diversity and reproductives systems. In Dattee *et al.* (eds.) *Reproductive biology and plant breeding*, p. 311-324. Springer-Verlag, New York.

[48] Op. cit., endnote 32

[49] Op. cit., endnote 39

[50] Kilian A and Kleinhofs A (1995) High degree of synteny in chromosomes of barley and rice. *Nucleic Acids Research*, (in press).

[51] Op, cit., endnote 39.

[52] Adams MW (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.

[53] National Research Council (1993) *Managing global genetic resources: agricultural crop issues and policies*. Academy Press, Washington DC.

[54] For example, in lawsuits about disputed paternity, murder and rape.

[55] Van Laecke K, Van Bockstaele E and De Loose M (1995) *Evaluation of RAPD-markers for the identification of ryegrass varieties*. UPOV Working Group on Biochemical and Molecular Techniques and DNA Profiling in Particular, UPOV Paper BMT/3/3.

[56] 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.

[57] Semon S (1995) *The impact of the UPOV 1991 Act upon seed production and research*. University of Edinburgh, UK. (M.Sc. Thesis)

[58] dos Santos JB, Nienhuis J, Skroch P, Tivang J, Slocum MK (1994) Comparison of RAPD and RFLP genetic markers in determining genetic similarity among *Brassica oleracea* L. genotypes. *Theoretical Applied Genetics,* 87:909-915.

[59] Keystone International Dialogue Series on Plant Genetic Resources, Oslo Plenary Session, Final Consensus Report: Global Initiative for the Security and Sustainable Use of Plant Genetic Resources, 31 May-4 June 1991, p. iv.

[60] FAO (1994) *Revision of the International Undertaking: Analysis of some technical, economic and legal aspects for consideration in stage II.* CPGR-Ex1/94/5 Supp.; Hardon JJ, Vosman B and Hintum TJL (1994) *Identifying genetic resources and their origin: the capabilities and limitations of modern biochemical and legal systems*. CPGR Background Study Paper No. 4, FAO.

# ANNEX 1-2
# State of the Art: Methods for Conservation

## A1-2.1 INTRODUCTION

Both *in situ* and *ex situ* conservation methods are important and should be considered as complementary, especially when the aim is to conserve specific genotypes.

*Ex situ* conservation is generally used to safeguard populations that are at present or potentially in danger of physical destruction, replacement (e.g. of landraces by modern varieties) or genetic deterioration. *Ex situ* collections may also be established to ensure the ready availability of reproductive material, either through a genebank or through a production source (a planting) in the area where the material is to be used. This will often be the case where there is a need for immediate use on a large scale, e.g., for commercial improvement of a species through breeding.

*In-situ* conservation refers to the maintenance of a species in its natural habitat. Strictly speaking, *in situ* conservation requires the conservation of the whole ecosystem - natural and cultural - of which the species is part,[1] since it is only by maintaining the integrity of the ecosystem that the complex and often unknown demands of the specific target species can be met. Likewise, on-farm conservation - a subset of *in situ* - requires maintenance of the agro-ecosystem and the human element of cultivation. *In situ* conservation is especially useful for species which cannot be established or regenerated outside their natural habitats.[2] It may also have advantages for conserving species with non-orthodox seed, and for some vegetatively propagated species.

## A1-2.2 COLLECTING

Most plant collecting to date has been carried out by plant breeders with the result that many agronomically useful collections exist outside of formal genetic resources conservation units. These are the collections that are the most studied.[3] Many breeders go directly to other breeders or to the field[4] to look for diversity if they do not find it in their own collections, rather than going to major public collections.[5]

Ideally, plant collectors attempt to collect for conservation purposes, a representative sample, in both nature and size, of the total genetic variation in the sample area.[6] In practice, however, whether a representative sample is collected depends very much on the objectives and resources of the collector. Mission-oriented collecting may often only target those ecotypes for which there is an immediate need (e.g., breeding for resistance to a pest or pathogen) rather than trying to collect a wide range of diversity for future, as yet unknown, needs. Many of today's largest collections are the legacy of such collecting strategies (e.g. wheat). In more recent times there has been a shift to maximize the extent of gene pool coverage of particular species in the *ex situ* collections. This has now led to the use of sampling strategies to collect as much genetic diversity as possible for storage in a reasonable number of samples.

The number of seeds which constitute a representative sample may differ depending on the type of population being sampled and on the intended purpose of the sample.[7] For instance, while the FAO/IPGRI International Genebank Standards for Base Collections recommend that 1,000 viable seeds of an accession is an absolute minimum,[8] they also recognize that more seeds are necessary in the case of genetically heterogeneous accessions. Some genebanks, such as the Royal Botanic Gardens at Kew in the United Kingdom, employ a strategy of collecting as much seed as possible and storing it for as long as possible without any regeneration.

Different sampling techniques (e.g., probability or purposive sampling) have been advocated by different researchers and used on collecting missions.[9] Collecting strategies also differ according to the types of samples that are required and the reproductive biology of the species,[10] some of which — such as vegetatively reproducing[11] and woody species[12] — present practical difficulties. However, advances in plant tissue culture have made available a range of techniques which can be used for the *in vitro* collecting of problem species such as cocoa, coconut, *Digitaria eriantha* and *Cynodon dactylon*.[13] 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.[14]

## A1-2.3 TECHNOLOGIES AND METHODS FOR *EX SITU* CONSERVATION

Methods for germplasm storage are determined by a number of factors:

**(i) Purpose:** Programmes which intend to "conserve for posterity" by conserving as much genetic diversity as possible for future use may choose different conservation methods than those conserving material for present and short-term use;

**(ii) Storage Behaviour:** The inherent longevity and physiological storage behaviour of the species ( i.e. orthodox, recalcitrant or intermediate) as well as the quality of material collected may dictate the mode of conservation;[15]

**(iii) Resources:** The financial resources available, human and institutional capacities and technologies, will all influence the choice of storage method (Table A1.6).

Seeds are usually the most convenient form for long-term storage of plant germplasm. However, there are a large number of important tropical and sub-tropical crop species whose seeds do not survive under cold storage and/or the drying conditions used in conventional *ex situ* conservation (Table A1.5). These seeds - known as "recalcitrant" - can typically be conserved *ex situ* for periods of only weeks or months. Agronomically important species producing recalcitrant seeds include most tropical fruit trees (e.g. mango, jackfruit, citrus, avocado), cash crops (e.g. coffee, tea, cocoa, coconut), forest trees (e.g. oaks, maples, *Podocarpus* spp., *Araucaria* spp.), some spices (e.g. cinnamon, nutmeg) and crops grown in riparian environments such as wild rice, wasabi and watercress. Careful adjustments of the storage environment (humidity, temperature) have allowed some species to be conserved for longer periods of time. Examples include citrus, oil-palm, neem, coffee and several others.[16] IPGRI has recently produced an extensive review of the storage behaviour of 7,000 plant species.[17]

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 reserves alone. Many large tree species produce non-orthodox seeds and their size precludes the preservation of more than a few specimens. The approach to storage may also depend on the biology of the species and the choice of plant organs to be conserved and regenerated.

**Table A1.5 Some species with recalcitrant seeds**[18]

| Species | Crop name |
|---|---|
| *Araucaria* spp. | Araucaria |
| *Castanea* spp. | Chestnut |
| *Chrysophyllum cainito* | Caimito |
| *Cinnamomum zeylanicum* | Cinnamon |
| *Durio* spp. | Durian |
| *Erythroxylum coca* | Coca |
| *Garcinia* spp. | Mangosteen |
| *Hevea brasilianensis* | Rubber tree |
| *Diospyros* spp. | Ebony |
| *Cocos nucifera* | Coconut |
| *Diospyros* spp. | Ebony |
| *Mangifera* spp. | Mango |
| *Manilkara achras* | Zapote |
| *Myristica fragrans* | Nutmeg |
| *Nephelium lappaceum* | Rambutan |
| *Spondias* spp. | Jocote |
| *Swietenia mahagoni* | Mahogony |
| *Syzygium aromaticum* | Clove |
| *Theobroma cacao* | Cocoa |
| *Persea* spp. | Avocado |
| *Quercus* spp. | Oak |
| *Persea* spp. | Avocado |
| *Quercus* spp. | Oak |
| *Thea sinensis* | Tea |

### A1-2.3.1 Storage of seeds in conventional seed genebanks

Many crop species have "orthodox" seeds which can be dried to a low moisture content (i.e. 3% to 7% seed moisture content,[19] depending on the species) and stored at low temperatures (e.g., -20˚C) without losing their viability over long periods of time.[20] 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 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.[21]

**Table A1.6 Technologies for *ex situ* conservation of different types of PGRFA**

| Storage technology | Type | Appropriate function |
|---|---|---|
| Desiccated seeds at low temperature (-18ºC) and 3-7% moisture content | Orthodox seeds | Long-term conservation (base collection); provision of accessions for use (active collections) |
| Desiccated seeds at cool temperature[22] | Orthodox seeds | Provision of accessions for use (active and working collections); medium-term conservation (base collections) |
| 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 and working collections) |
| Cultivation of entire plants in field genebank | Vegetative species and some non-orthodox seeded species | Short- or medium-term conservation (base collections); provision of accessions for use (active collections) |
| Slow growth under serial *in vitro* propagation | Vegetative species and some non-orthodox seeded species | Medium-term conservation; provision of accessions for use (active collections) |
| Cryopreservation at -196˚C in liquid nitrogen or -154˚C to -196˚C in $N_2$ vapour | Seeds, pollen, tissue, cells, embryos of species capable of *in vitro* regeneration after drying and freezing | Long-term conservation |
| Freeze-dried seeds or tissue | Seeds or plant tissue | Medium- to long-term conservation, depending on the species |

## A1-2.3.2 Maintenance of living plants in field genebanks

Species that do not easily produce seed (e.g. many vegetatively propagated crops), which have to be conserved clonally in order to maintain their genetic composition or which have recalcitrant seeds are usually conserved in field genebanks. These are plants assembled and grown in a field as a living collection of accessions. Such collections are often used for the *ex situ* conservation of perennial species such as fruit trees or crops requiring annual propagation.

While field collections have a conservation role, some also function as working collections for experimental purposes, as is the case for species such as cocoa, rubber, coconut, mango, cassava and yam.

Field genebanks are especially vulnerable to germplasm losses due to pests and disease or natural disasters such as hurricanes or fires. For instance, on 22 August 1992 the World Sugarcane Germplasm Collection in Florida, United States, was hit by hurricane Andrew and 46% of the *Saccharum officinarum* collection was lost or damaged.[23] However, for some species there are no alternatives to field genebanks although they are usually considered to be effective only for short- to medium-term conservation. For this reason, it is generally recommended, where possible, to establish a safety duplicate of the living collection by maintaining the accessions under slow growth *in vitro* conditions (see below).

### A1-2.3.3 *In vitro* storage[24]

In *in vitro* collections, germplasm accessions are kept as sterile plant tissue or plantlets maintained either under slow growth on nutrient gels or cryopreserved in liquid nitrogen. Slow-growth techniques are a short to medium-term storage option and are used routinely for germplasm conservation in vegetatively propagated species like banana, plantain, cassava and potato. Under slow-growth conditions, intervals between regeneration (subculture) can be extended to 1-4 years for many species, thereby dramatically reducing laboratory space and staff time required.

Large collections which are currently stored in this way include the collections of cassava at CIAT, potato at CIP, *Musa* spp. at the INIBAP Transit Centre in Leuven, and temperate fruit species at USDA. The advantages of this form of germplasm storage are that the collection is maintained under sterile conditions in a controlled environment (free of fungal and bacterial diseases, climatic fluctuations, etc.), and plantlets can be rapidly propagated and disseminated from the active genebank when required. Optimal methods for the *in vitro* propagation of plant material still need to be developed for many species, and the regeneration issues of both genetic integrity and genetic drift need to be addressed.

Cryopreservation involves storage of plant material at low temperatures (-196°C), in liquid nitrogen or nitrogen vapour (-154°C to -196°C). At this temperature, cell division and metabolic processes stop, and plant material can thus be stored without modification or alteration for long periods of time. Cryopreservation of those species which can easily be regenerated[25] into whole plants is a promising option for the safe, long-term storage of germplasm of vegetatively propagated species and species with recalcitrant seed.[26] It can also be used as a technique for the long-term storage of many orthodox species.[27]

Cryopreservation requires limited space, protects material from contamination, involves very little maintenance and is considered to be a cost-effective option.[28] With a few exceptions, cryopreservation protocols are still in the development stage for most crop species, such as cassava.[29]

While cryopreservation techniques have been developed for over 80 plant species, at present such techniques are only routinely used across a range of genotypes of *Rubus*, *Pyrus*, *Solanum* and *Elaeis* spp. Research is needed to transform newer cryopreservation (encapsulation-dehydration,[30] vitrification and desiccation) and somatic embryogenesis technology into standard protocols that can be applied to a broad range of vegetatively propagated species or species with recalcitrant seed. However, the techniques required for successful cryopreservation of non-orthodox seeds are sophisticated and implementing a cryopreservation programme requires trained technical staff, advanced plant tissue culture facilities and increased transportation/handling costs to assure fresh materials. These constraints may present a barrier to effective technology transfer to many developing countries.

*In vitro* techniques complement other conservation strategies, especially field genebanks, and are particularly useful for the conservation of vegetatively propagated species and species with recalcitrant seeds. During the last 15 years, *in vitro* culture techniques have been developed for more than 1,000 plant species. However there are many stages in the *in vitro* conservation of any species; discrete procedures are required for tissue culture, storage and successful regeneration, prior to transfer to soils. All of these procedures will require significant research before they can be routinely applied in genebanks. All major problems at each stage have so far been solved only for strawberry,[31] although significant progress has been made for potato and cassava.

For some species, *in vitro* conservation may be the only *ex situ* option.[32] However there are two major technical problems associated with this method depending on the technique and the species. These are: (i) the potential for genetic instability causing genetic shift of the material as a result of somaclonal variation at the time of regeneration; and (ii) the often limited storage period for the tissue accession. Usually, organized cultures, such as shoots, are used for slow-growth storage at low temperatures since undifferentiated tissues, such as calli, are more vulnerable to somaclonal variation. With some root and tuber crops, temperate fruits, ornamental and horticultural species and a few forestry species, routine slow growth storage for 1-15 years is possible using cycles of up to 2 years before subculturing (regeneration).[33] Research work is being done to address these problems.

Successful *in vitro* collections of plantain, banana, cassava,[34] yam,[35] potato,[36] sweet potato[37] and *Allium* spp.[38] have been reported. However, it is notable that, as of 1994, only 37,600 accessions had been conserved by *in vitro* techniques worldwide.[39] 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 can limit the extent to which many genebanks apply tissue culture techniques.

Another promising method for conserving clonally propagated or recalcitrant seed species involves the production and storage of 'synthetic' seeds which consist of shoot tips or somatic embryos encapsulated in a gelatinous material.[40] This approach has been successful for alfalfa and is being applied to other species such as carrot, celery, grape, lettuce, mango, mulberry, orchard grass, sandalwood, soybean and spruce.[41]

Simple *in vitro* techniques, such as rapid micropropagation at room temperatures, are some of the biotechnological methods which are more easily transferable to developing countries. Obviously, more advanced applications of *in vitro* techniques, such as virus elimination by meristem culture or cryopreservation, will require higher levels of capacity in recipient countries. *In vitro* techniques can be used for myriad purposes, including germplasm collecting, disease elimination, healthy germplasm distribution, rapid multiplication of plantlets and enhancement of germination systems. For this reason, there is potential for the establishment of regional centres of excellence which cater both to the *in vitro* conservation and planting needs of the region.

### A1-2.3.4 Pollen storage

Assessment of pollen storage as an effective conservation strategy is currently at a preliminary stage. This form of *ex situ* germplasm storage, if widely applied, may provide a means to overcome the difficulties involved in preserving recalcitrant (desiccation-sensitive) seed species.

At present, pollen storage is not often used in genebanks but is practised among plant breeders to some extent. Even at this early stage of development, the potential advantages of this method can be readily appreciated; the relatively small quantity of the specimen required for a single accession, and the fact that pollen is less likely than seed to be infected by diseases, are chief among these. Pollen storage alone, however, cannot conserve the cytoplasmic genetic diversity of a species. A thorough assessment of the various aspects of this method is necessary if it is to be developed as an effective tool for *ex situ* conservation. In particular, research is needed to address the following basic questions:

- relevant aspects of the reproductive biology of the species in question (including an assessment of the potential drawbacks of excluding maternal genes by pollen sampling and the feasibility of ovule storage and *in vitro* fertilization techniques);
- the complementarity and comparative advantages of pollen storage with respect to other conservation methods;
- effective sampling techniques to cover a given gene pool or population adequately;
- the effectiveness of pollen as a means for the safe and practical movement of germplasm;
- procedures and strategies for the regeneration and use of pollen accessions.

### A1-2.3.5 Ultra-dry seed storage[44]

The most common method of *ex situ* conservation is to store seeds dried to 6-8% moisture content in sealed containers at -18°C. Despite the relative simplicity of this procedure, however, maintaining seed in cold storage is still problematic for many genebanks. Lack of proper refrigeration equipment, unreliable electricity supply, poor maintenance practices and high operating costs are some of the key constraints. Many genebanks, especially those in developing countries, lack the funds and other resources needed to perform these tasks effectively. Cost-effective, low-input technologies that can be adopted by resource-poor national programmes and smaller community-based genebanks are needed.

The “ultra-dry” method of seed storage which involves the maintenance of very dry seeds under ambient or partly cooled conditions may prove to be useful. Several studies carried out since the 1980s have shown that seeds (of various species) dried to very low moisture content (1-2%) and kept in moisture-proof containers can be stored at room temperature for long periods. These findings seem to obviate the need for expensive refrigeration and indicate that ultra-dry seed storage may be particularly practical for genebanks in the tropics. It should be noted that this method is not suitable for all species. In addition, the optimum seed moisture content for storage differs between species, and a limit to moisture content (below which seed can be damaged by further drying) has been noted. While ultra-dry seed storage shows considerable promise as a method of conservation, these and some other technical problems need to be resolved and an easy working protocol developed. Thorough guidelines for inexpensive, effective and practical procedures for drying seeds to optimal levels of seed moisture content need to be developed for a wide range of species.

### A1-2.3.6 Conservation of DNA or DNA sequences

It has been proposed that DNA "libraries" could be used to conserve total genomic information on a species.[43] However, total genomic information is not the same as total genetic diversity and the utility of this approach is limited for a number of reasons:

- While all the genes (but not their variants) may be represented in a DNA library, they will be effectively separated from their phenotypes. DNA libraries cannot therefore be directly screened by phenotype for useful agronomic traits.
- Any agronomic genes that can be identified (generally by sequence similarity to other genes) in a DNA library are only available for gene tranfer through genetic engineering. This limits their utility at present to single gene traits.
- DNA libraries are costly and time-consuming to construct and each library can represent only one sample.

The prinicipal utility of DNA libraries is for the isolation of useful genes and not as an alternative conservation strategy. The storage of isolated DNA may be extremely useful in providing base material to determine the evolutionary relationships of different accessions, or for the isolation of genes similar to those which have been isolated from other species. However, it is not possible to use this DNA to reconstruct any organism.

### A1-2.3.7 Botanical gardens[44]

At present, there are 1,500 botanical gardens worldwide. The vast majority of these - over 80% - maintain *ex situ* collections either outdoors or in greenhouses. The remaining 20% maintain seed banks under medium- to long-term storage conditions. Relatively few botanical gardens (35) use *in vitro* or cryopreservation techniques for conservation or handling of accessions. The role of most botanical gardens in conserving intra-specific crop diversity is generally limited because most conserve only a few accessions per species or taxon. It is estimated that the typical number of accessions per taxon is 1-5, and rarely reaches 10.

## A1-2.4 TYPES OF *EX SITU* COLLECTIONS

The basic features of some types of *ex situ* collections are outlined below:

- **Base collection.** A base collection is defined as "*a set of accessions, each of which should be distinct and, in terms of genetic integrity, as close as possible to the sample provided originally, which is preserved for the long-term future*".[45] The base collection for a crop gene pool or a species may be dispersed among several institutions. Normally, seeds will not be distributed to users from the base collection. Base collection regeneration should only be required as a result of a decline in seed viability below an acceptable level and not for supplying seed stocks for active use. Therefore, the storage conditions and seed quality have to be such that longevity is optimized.
- **Active collection.** Active collections are "*comprised of accessions, which are immediately available for multiplication, distribution and use*".[46] Accessions which are more in demand can usually be stored under less stringent conditions than those required for base collections since there will be a large turn over of seed stocks. Hence, for an active collection, the frequency of regeneration should be determined by the rate of stock depletion and not by the normal longevity of the storage method for the species concerned.
- **Working collection.** Plant breeders may hold "working" collections which are grown out regularly for selection and crossing purposes as part of their breeding programmes. Most genebanks usually do not have working collections.
- **Community seed collection.** This can be any type of collection or genebank which serves the needs of a community.

A core collection is a sub-set of an entire collection which represents, with a minimum of repetition, the genetic diversity of a crop species and its wild relatives.[47]

## A1-2.5 MANAGEMENT OF *EX SITU* COLLECTIONS

### A1-2.5.1 Duplication

Most *ex situ* conservation strategies include the duplication of unique accessions at another location for safety reasons. Unneccessary duplication of accessions between and within genebanks is a serious waste of resources. The difficulties involved in identifying probable duplication between genebanks are considerable, and have recently been reviewed in the scientific literature.[48]

### A1-2.5.2 Regeneration of genebank accessions

Regeneration of genebank accessions is an area of genebank management which tends to be neglected, particularly in budgeting.[49] Regeneration should be carried out only when necessary to limit genetic changes (genetic drift or shift) in the accession due to environmental selection during the process; genetic drift can also occur if sufficiently large populations are not grown out.[50]

Ideally, regeneration is carried out under neutral selection conditions, to reduce competition and thereby minimize genetic change through selection. However, this is not always possible. A certain degree of genetic change is virtually inevitable, especially when regeneration takes place under conditions markedly different from those at the original collection site. Ideally the accessions might be returned for regeneration at the collection site; however, this is impractical in most cases. The next best solution is for regeneration to be conducted under conditions closely approximating those at the original collection site.

The danger of genetic change during regeneration applies more to heterogeneous populations/accessions than to homogeneous ones. This is because the probability of losing an allele (particularly a low-frequency allele) increases with:

(a) smaller population sizes for regeneration;

(b) more stressful growing out conditions.

Changes in an accession's genetic make-up during regeneration are of particular concern in the case of locally adapted landraces, which tend to be heterogeneous populations. Certain genotypes and genes may be lost through selection pressure. In this case, regeneration should be undertaken at the collection site under the farmer's normal growing conditions. Where this is not an option, alternative approaches to conservation might be considered; such as a strategy employing *in situ* methods, perhaps together with *ex situ* methods. However, it should be noted that with proper management and resources it is still possible to regenerate most accessions adequately outside the location of collecting, with minimal loss of alleles.

The complexity and cost of maintaining the genetic integrity of accessions of a crop during regeneration depends on the reproductive biology of the species.[51] For instance, it is more difficult and costly to maintain the genetic integrity of cross pollinated crops than self-pollinated crops during regeneration.[52] The complexity and expense[53] are higher for species which are insect pollinated.[54] The reproductive biology of a large number of crops (including the wild relatives of major crops and many underutilized or minor crops is not yet sufficiently understood, making the development of regeneration procedures for these crops quite difficult. This is a matter requiring urgent research.[55]

### A1-2.5.3 Passport, characterization and evaluation data

Genetic resources are of little use to plant breeders or genebank managers unless the material is accompanied by adequate information. As a minimum, passport data should be gathered on each accession at the time of collection. Passport data include such information as country of origin, location of collection site, species name and local names which are 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.[56]

Characterization data are descriptors for characters that are highly heritable, that can be seen easily by the eye (except, of course, for molecular characters) and that are expressed in all environments. Such data describe the attributes of the species sampled, including plant height, leaf morphology, flower colour and number of seeds per pod, and are essential information for the genebank curator to distinguish between samples in the collection. To facilitate and standardize the characterization of variants of different crop species, IPGRI has published extensive Descriptor Lists for many crop species (see Table A1.1). Other descriptor lists have been published by COMECON and UPOV. Such descriptors constitute the characterization data that are important for PGRFA management and use. Genebank managers will often modify such descriptor lists somewhat to tailor them to their particular needs and those of the user-community.

Many agronomic traits that are required by breeders are too genetically complex to be screened for in the preliminary characterization of germplasm accessions. These data are usually 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 the stage at which most value is added to plant genetic resources collections because only then does information 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. Unfortunately, as noted previously, most genebanks have incomplete passport and characterization data for their accessions. Evaluation information, when available, is often not in a user friendly-form.

### A1-2.5.4 Germplasm health aspects of *ex situ* management

Infection or contamination with pathogens may cause a number of problems in germplasm management:

- pathogens may affect seed longevity;[57]
- plant diseases may affect germplasm characterization and evaluation by masking the traits of the genotype;
- pathogens may destroy susceptible accessions;
- pathogens may move internationally with germplasm.[58]

In a number of cases, the introduction of a new pest or pathogen into a country or region can clearly be traced to germplasm introductions. The fear of increased risk from pests and pathogens may lead countries to impose strict plant quarantine regulations and limit germplasm exchange in general. An example is the discontinuation of coconut germplasm exchange due to the fear of spreading cadang-cadang viroid-like RNAs.[59]

Of the 1,050 *Musa* clones held at INIBAP's Transit Center in Leuven, Belgium, only 35% are virus-tested and available for distribution without restrictions. About the same proportion of the collection has not been tested, but is assumed to be healthy.[60] Of the 2,700 accessions of wild and primitive potato species held at the Centre for Genetic Resources in the Netherlands, only 800 have been tested for seed-borne pathogens and are thus available to potential users.[61] To help overcome these problems, FAO and IPGRI have developed a series of Technical Guidelines on the Safe Movement of Germplasm of different crop species, which provide relevant information on disease indexing and other procedures that help to ensure phytosanitary safety when germplasm is moved internationally.[62] Also, new *in vitro* techniques such as thermotherapy followed by meristem culture have been shown to allow the elimination of disease organisms, particularly viruses, from plant material.[63]

## A1-2.6 METHODS FOR *IN SITU* CONSERVATION

While the *ex situ* conservation of the intra-species genetic diversity of crop plants has traditionally been of concern to the agricultural and plant breeding community, *in situ* conservation has been dealt with by agencies responsible for the conservation of ecosystems, habitats and the general inter-species diversity of wildlife therein. As a result, the conservation focus of protected areas has usually been on the level of ecosystems or species numbers, not on the maintenance of the intra-specific genetic diversity of crop genetic resources or other PGRFA.

*In situ* conservation of plant genetic resources has a number of advantages:

- It allows the possibility of conserving a large range of potentially interesting alleles:
- It allows natural evolution to continue, providing breeders with a dynamic source of resistance and other traits. This is in contrast to *ex situ* conservation, which maintains reproductive material (seeds, pollen) in a static non-evolutionary state:
- It can serve several purposes at once, since gene pools of value to different sectors (e.g. crop breeding, forestry, forage production, wildlife) may often overlap, and so can be maintained in the same area:
- It facilitates research on species in their natural habitats:
- It assures protection of associated species, which although of no known economic value, may contribute to the functioning and long-term productivity of ecosystems.

Where genetic resources conservation considerations exist among managers of protected areas, they may be considered an additional responsibility, lower in priority from a general biodiversity conservation perspective. Furthermore, links between those concerned with *in situ* biodiversity conservation and those concerned with *in situ* plant genetic resources for food and agriculture are extremely weak in almost all countries. Opportunities for the conservation of PGRFA may be lost through lack of communication between all of the relevant actors.

### A1-2.6.1 Conservation of species and ecosystems

#### Ecogeographic surveys

An ecogeographic survey is a process of gathering and synthesizing taxonomic, geographic and ecological data to determine the type and distribution of resources present in a particular region.[64]

The results are predictive and can be used to assist in the formulation of collecting and conservation priorities. As such, ecogeographic surveys can be of benefit to both *in situ* and *ex situ* approaches.[65] There are three major components in most ecogeographic studies: the distribution of particular species in particular regions and ecosystems; patterns of intra-specific diversity; and the relationship between survival and frequency of variants and associated ecological conditions.[66] Agro-ecological surveys are similar to ecogeographic surveys but also take into account the social factors maintaining agricultural genetic resources.

### Species conservation

One of the first steps in the *in situ* conservation of a target species or population is to determine its status in the area where it grows. It is also important to determine the factors known to threaten the survival of the species, and its vulnerability at various stages of its life cycle. The Species Survival Commission Steering Committee of the World Conservation Union (IUCN) has recently developed new categories for threatened species based on population sizes, fragmentation and population viability analysis[67] (Figure A1.1).

**IUCN threatened species categories**

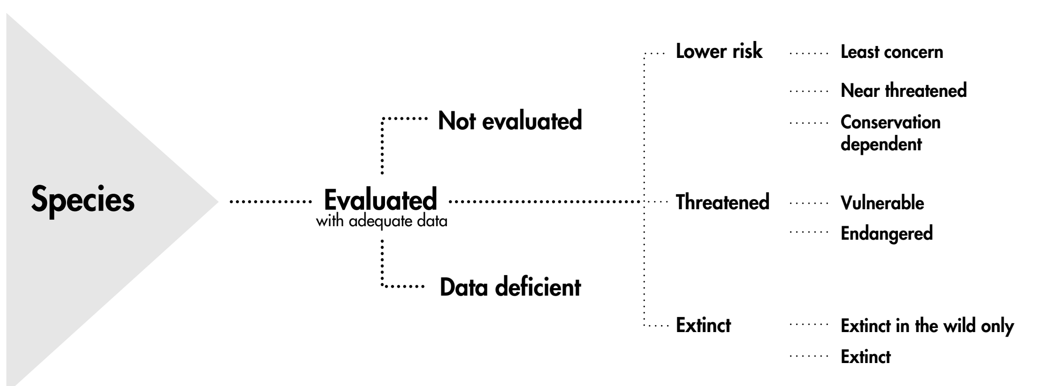



Figure A1.1

For threatened species, it is important to determine the minimum viable population size in the target area. The concept of minimum viable population size implies that a population in a given habitat cannot persist if the numbers of organisms (i.e. the genetic diversity of the population gene pool) is reduced below a certain threshold. Several approaches to estimating minimum viable population size have been taken.[68]

### Recovery plan

Where the target species is considered endangered in its geographical range, it may be necessary to develop a recovery plan to ensure its survival. Box A1.3 outlines a typical recovery plan. It must be noted that the cost for the development and implementation of recovery plans is often prohibitive and thus priorities will have to be set. In some countries, such as the United States, development of recovery plans is mandatory for formally listed endangered species.

### Redressing the damage - Restoration ecology

Two techniques which are increasingly being used in *in situ* conservation, particularly where the habitat of the target species has been irreversibly degraded[69] are habitat restoration and rehabilitation. Both require the elimination of the factors leading to the degradation of the ecosystem in the first place and the replacement of the components that have disappeared. They differ in that rehabilitation involves the actual repair of a damaged ecosystem while restoration usually involves the reconstruction of a natural or semi-natural ecosystem on degraded or modified land. Restoration is primarily concerned with the replacement of the plant community, generally by planting and subsequent care. These techniques are still in their infancy and few guidelines are available for reference.[70]

### Legislative actions

Many countries have resorted to the establishment of legal instruments to protect their endangered flora against excessive exploitation. However, these apply mostly to species of direct economic value such as timber, medicinal, industrial plants, and species with traditional/cultural values. Only rarely are species protected because of their relation to agricultural crops.

Regulations often contain national lists of protected plant species. In some cases, the area of distribution of rare species is protected in a protected system. The legislative protection of plant species, based on their reduction in numbers below a minimum viable population, is unlikely to apply generally to the conservation of plant genetic resources of utility to agriculture (with the exception of some wild relatives), as much of the genetic diversity of the species will already have been lost.

### Ecosystem protection

At the ecosystem level, *in situ* conservation describes the setting up of Protected Areas, defined by IUCN as "*An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means*".

IUCN classifies Protected Areas into six categories according to broad management objectives (Box A1.4). Many of these areas already contain PGRFA (generally inadvertently). IUCN has recently prepared a set of Guidelines for Protected Area Management Categories to assist in the preparation of national plans for protected areas.[71]

## A1-2.6.2 Protected Areas

The effectiveness of Protected Areas for conserving genetic diversity has been questioned in the light of findings that many have no species or genotype inventories; management systems often do not take account of species diversity, much less of intra-specific genetic diversity. Moreover, detailed ecogeographic surveys are often not carried out.[72] In addition, many Protected Areas do not meet minimum conservation requirements for maintaining inter-specific diversity and lack the monitoring function that is necessary to ensure conservation.[73]

**Box A1.3 Species recovery plan**[74]

A typical recovery plan should include:

- Full description of the taxon
- Details of any taxonomic and genetic variation
- Present and past distribution
- Current numbers and status
- Population biology, reproductive biology and life history
- Habitat and ecology
- Factors limiting distribution of the plant
- Actual and potential threats
- Conservation measures required
- Recovery objectives and scale of the project
- Criteria to measure success of recovery
- Implementation schedule
- Horticultural and propagation techniques
- Arrangements for aftercare and monitoring
- Staff needed and a workplan for them
- Full costing

### Genetic reserves

At present, most Protected Areas do not give sufficient consideration to intra-specific genetic variation of crops and their wild relatives. For instance, a European survey of wild crop relatives of apples, plums, cherries, peaches, almonds and *Allium* species, found that while some Protected Areas overlapped with the geographical ranges of the wild species, there was very little specific consideration of these genetic resources within the Protected Areas' descriptions or management plans.[75] It may be necessary to protect multiple populations in order to capture a reasonable level of the allelic variation of a species.[76] A modified *in situ* concept of *genetic reserves* has been proposed as a strategy to maintain the population level genetic variation of one or more species in their natural range or habitat.[77]

It is important that a genetic reserve has a clearly defined conservation objective and management plan (Box A1.5). In most cases, the maintenance of numbers and diversity of the target species is likely to be a basic goal for all genetic reserves, but other objectives, such as maintaining populations with active speciation, adaptation to acidic soils or resistance to diseases, might also be considered. Once established, it will be necessary to monitor the progress of the gene reserve operation to see whether the conservation objectives are being met or not, and to guide further management decisions.

### Managed *in situ* areas - the human dimension

In the past, many Protected Areas consciously excluded human activity. Now, it is widely accepted that there is a need to link environmental protection to social and economic development. This "new" concept of Protected Area management is based on the recognition that humans exist within and as an integral part of natural ecosystems[78] and that environmental protection without economic development cannot be secure or sustainable.

Many Protected Areas are heavily populated with residents dependent on the resources therein for their livelihood security.[79] In South and Southeast Asia, for example, some 200 to 300 million resource poor people are dependent on forest resources for their livelihood security.[80] There is mounting evidence that the exclusion of local peoples from Protected Areas may not only have an adverse effect on their food and livelihood security,[81] but also that *in situ* conservation measures that exclude human activity from newly protected areas, may actually lead to degradation of those areas, as a result of the lack of human management.

This has been shown to be the case in particular where traditional management or tenure systems have been discouraged, resulting in the erosion of range vegetation in arid and semi-arid areas.[82] The movement of several hundred pastoralist Pokot families from the Masol plains of Kenya resulted in massive changes in the vegetation, for example.[83]

**Box A1.4 1994 IUCN Revised Protected Area Categories**[84]

**Category I**: Strict Nature Reserve/Wilderness Area. To protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment for scientific study, environmental monitoring, education and maintenance of genetic resources in a dynamic and evolutionary state. There are two subcategories: I(a) includes protected areas managed mainly for scientific research and monitoring; and I(b) includes protected areas managed mainly for wilderness protection, subsistence and recreation.

**Category II**: National Park. To protect outstanding natural and scenic areas of national or international significance for scientific, educational and recreational use. These are relatively large areas not materially altered by human activity and where extractive resource uses are not allowed.

**Category III**: National Monument/Natural Landmark. To protect and preserve nationally significant natural features because of their special interest or unique characteristics. These are relatively small areas focused on the protection of specific features.

**Category IV**: Habitat/Species Management Area. To assure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities or physical features of the environment where these may require specific human manipulation for their perpetuation. Controlled harvesting of some resources may be permitted.

**Category V**: Protected Landscapes and Seascapes. To maintain nationally significant natural landscapes that are characteristic of the harmonious interaction of humans and land while providing opportunities for public enjoyment through recreation and tourism. These are mixed cultural/natural landscapes of high scenic value where traditional land uses are maintained.

**Category VI**: Managed Resource Protected Area. This is a new category designed to include areas that ensure long-term protection and maintenance of biological diversity while providing a sustainable flow of natural products and services to meet community needs. They are intended to be relatively large and predominantly unmodified natural systems where traditional and sustainable resource uses are encouraged.

The inclusion of human activity in Protected Area management plans represents a reversal of traditional conservation policies. Some Protected Area managers are including considerations of local communities and direct users of genetic resources within their management plans.[85] As a result of this and other factors, the growing trend in Protected Area management is an increase in the number of IUCN management category VI schemes which focus on integrating conservation and development. Similarly, the principles of joint forest management are now being extended to protected areas to reconcile the twin goals of conservation and local livelihood security (Box A1.6). However the level of effective participation open to communities within designated areas, in decision-making and other planning functions has been widely questioned.[86]

### Biosphere reserves: a potential model?

Biosphere reserves are *"areas of terrestrial and coastal/marine ecosystems, where, through appropriate zoning patterns and management mechanisms, the conservation of ecosystems and their biodiversity is combined with the sustainable use of natural resources for the benefit of local communities, including relevant research, monitoring, education and training activities"*. One fundamental difference between biosphere reserves and other protected areas is the formers' stated aim of developing a biosphere reserve network representative of the world's ecosystems. However biosphere reserve designations carry no legal requirements binding members to certain activities or management standards.[87]

#### Box A1.5 Elements of a management plan for genetic reserves[88]

**Preamble**: conservation objective, reasons for siting of reserve, place of reserve in overall conservation strategy.

**Taxon description**: taxonomy (classification, delimitation, description, iconography, identification aids), wider distribution, habitat preferences, phenology, breeding systems, genotypic and phenotypic variation, biotic interaction (e.g. pollinators, dispersal agents, herbivores, pests, pathogens, symbionts), local name(s) and uses, other uses, present conservation activities (*ex-situ* and *in-situ*) and threats of genetic erosion.

**Site evaluation**: evaluation of population of the target taxon, reserve sustainability, factors influencing management (legal, constraint of tenure and access), external factors (e.g. climate change, political considerations), obligations to local people (e.g. allowing sustainable harvesting) and anthropomorphic influences.

**Site description**: location (latitude, longitude, altitude), map coverage, photographs (including aerial), physical description, (geology, geomorphology, climate, hydrology, soils), human population (both within reserve and around it), land-use and land tenure (and history of both), vegetation and flora, fauna, cultural significance, public interest (including educational and recreational potential), bibliography and register of scientific research.

**Status of target taxon in the reserve**: distribution, abundance, demography and genetic structure and diversity of the target taxon within the site, ecology within the reserve, interaction with associate fauna and flora, specific threats to population(s).

**Site objectives and policy**: site objectives, control of human intervention, allowable sustainable harvesting by local people and general genetic resources exploitation.

**Prescription**: details (timing, frequency, duration, etc.) of management interventions that will need to be carried out, schedule of ecological and genetic monitoring, population mapping, staffing requirements, budget and project register.

UNESCO has developed the Man and the Biosphere (MAB) Programme (Box A1.7) as an interdisciplinary programme of research and training intended to serve as the basis for the rational use and conservation of the resources of the biosphere, and for the improvement of the global relationship between people and the environment. The planning and management model developed by MAB consists of a core area, surrounded by a buffer zone and ringed by a transition zone. Biosphere reserves are considered to differ from either World Heritage[89] or Ramsar[90] sites because the human component (both in the sense of human presence and management) is vital to their function.[91]

The UNESCO Biosphere concept has better provisions for human activity and sustainable development than most Protected Area schemes. It has tended however to focus on general biodiversity and representative ecosystems rather than on conserving the plant genetic diversity that is of direct utility to humanity in terms of livelihood security.

**Box A1.6 Joint management for conservation**[92]

A joint management regime can be defined as an institutional arrangement by which governmental agencies with jurisdiction over natural resources, organized users of such resources (user groups) and other interested bodies (e.g. business, industries, commerce, research institu-tions, environment and development non-governmental organizations (NGOs) enter into an agreement covering a specific territory and all or part of the resources therein contained. The agreement identifies:

- a body of resources and the range of sustainable uses it can provide;
- a system of rights and obligations concerning such sustainable uses;
- procedures for the enforcement of rights and obligations;
- procedures for taking collective decisions and dealing with conflicts affecting the interests of all parties to the agreement;
- specific rules for the actions that subjects are expected to take under various circumstances.

A joint management agreement (JMA) assumes multiplicity and diversity in management. Various social actors (stakeholders) possess diverse capacities with respect to a given body of resources, and the complementarity of their distinctive roles is stressed and built upon.

The challenge is to create a situation where the pay-offs are greater for collaboration than for competition. A JMA also stands on the concept of "common good", the belief that it is possible to identify a course of action that harmonizes different interests while responding, at least to some extent, to all of them. Finally, it stands on management as a process amenable to on-going review and improvements as opposed to the strict application of a set of established rules.

It should be noted that, in rare cases, provisions for the conservation of the genetic resources of some plant species have been incorporated in biosphere reserve management objectives. For example, the Sierra de Manantlan Biosphere Reserve was created by the Mexican Government specifically to protect maize and other wild crop relatives. The reserve, covering 139,000 hectares, contains the site where a new species[93] of perennial maize (*Zea diploperennis*) was first reported in 1979.

### A1-2.6.3 On-farm management and improvement of plant genetic resources

On-farm management and improvement *"provides a mechanism by which the evolutionary systems that are responsible for the generation of variability are conserved."*[94] In other words, the processes which generate diversity are allowed to continue. Landraces do not remain static but continue to grow and evolve. On-farm management and improvement of landraces may be a useful strategy for maintaining adaptive capacity of landraces while contributing to sustainable development and community benefit.

Strengthening the on-farm conservation of plant genetic resources calls for the design of programmes that simultaneously increase income and productivity but do not rely on the displacement of genetic diversity. This is a formidable challenge as the dynamics of complex farming systems have to be better understood and several cultural and socio-economic factors need to be addressed. On-farm management programmes (combining elements of both conservation and development) should build upon and strengthen local systems of knowledge and management, local institutions and social organization. Approaches of this type benefit from the use of innovative extension methods, such as group demonstrations, community-level workshops, fairs and extension visits. Funding support of current projects, however, may be too short-term to realize benefits from what is inevitably a long-term process.

It would also appear that the spread and scaling up of successful on-farm conservation projects are heavily dependent on the existence of an appropriate macro-economic and policy environment. For example, the following national policies may influence the success and sustainability of on-farm management and improvement of PGRFA: subsidies on agricultural inputs; price controls on inputs and outputs, seed regulatory frameworks; priorities within the agricultural research and extension system; farm credit policies; and intellectual property rights.

There are few coordinated programmes of on-farm management and improvement and, therefore, no clear typology of methods. On-farm activities might be grouped into three provisional categories:

- **Sector-wide approaches**, involving changes in the policy environment, and in extension services, to promote on-farm conservation;
- **Targeted approaches**, involving a focus on the conservation of landraces of particular significance at local, national, regional or global level. Conservation is a primary purpose, although increasing the availability of enhanced seed for breeders as well as farmers is a clear goal;[95]

- **Integrated conservation and development approaches**, involving various NGOs worldwide engaged in grassroots PGRFA activities and sometimes linked to participatory breeding (e.g. the Community Biodiversity Development and Conservation Programme[96] or the MASIPAG Programme (Farmer Scientist Partnership for the Advancement of Science and Agriculture).[97]

### Box A1.7 UNESCO's Man and the Biosphere Programme

UNESCO's Man and the Biosphere Programme is guided by the MAB International Coordinating Council consisting of 30 Member States elected by the UNESCO General Conference. Programme activities are conducted in more than 100 countries under the direction of MAB National Committees or focal points. Based on its experience in 14 project areas developed from the beginning of the programme in 1971 until the early 1990s, MAB is now entering a new phase, focusing on the following elements:

1. The development of the existing network of sites, identified as biosphere reserves, of which there are 328 in 82 countries as of June 1995. The future development of the World Network of Biosphere Reserves is guided by the Strategy and Statutory Framework for the World Network drawn up at the International Conference on Biosphere Reserves.[98]
2. Continuing efforts to reconcile conservation and the sustainable use of biological diversity with socio-economic development and maintenance of cultural values, at the ecosystem- and landscape-levels, covering different geographical units such as catchment basins,land-water interfaces and urban-rural systems in different parts of the world.
3. Building up human and institutional capacities, including communication networks using modern technologies, to help countries address complex, cross-sectoral issues of environment and development This new phase of the MAB Programme is to be conducted in close cooperation with the appropriate partners such as UNEP, FAO, ICSU, IUCN, ISSC and relevant programmes such as Diversitas (UNESCO, IUBS, SCOPE), Ecotechnie (UNESCO, Cousteau Foundation), People and Plants (UNESCO, WWF, Royal Botanic Gardens at Kew), the Global Terrestrial Observing System (UNESCO, UNEP, FAO, WMO and ISCU), as well as with other relevant UNESCO activities.

None of the above approaches have been subject to extensive research or evaluation. There are, however, on-farm conservation projects which present opportunities for studying the effectiveness of a particular approach. For example, a project following the "targeted" approach was initiated in 1988 on 21 farms in the drought-prone areas of Welo and Shewa provinces in Ethiopia. The project covers species including sorghum, chickpea, teff, field peas and maize. In collaboration with the national genebank, farmers select populations grown in their fields by phenotype. The populations are maintained as distinct from each other, although the system allows for pooling similar landraces and even the introgession of valuable genes from exotic sources.

This project (along with a similar one, also in Ethiopia, started in 1994) could provide the basis for assessing the following:

- definition of goals, including details of the populations and traits (number of alleles, adaptive properties) that should be conserved;
- measuring diversity and comparing changes between *in situ* versus *ex situ* populations;
- measuring the selection efficiency and possible improvements (phenotypic recurrent selection, progeny tests, grid selection, participatory breeding);
- the loss of diversity through selection;
- monitoring undesirable gene flow between *in situ* and other populations;
- ascertaining the requirements for evaluation and characterization data;
- how the genetic material used in on-farm programmes can be documented to facilitate conservation and its availability to other potential users.

Assessments of such factors will be necessary for the future development of on-farm approaches. Without such knowledge, it will be difficult to know for sure what on-farm management strategies can contribute to conservation and development efforts.

The grassroots approach is usually directly linked to development and use. The purpose may be to reintroduce old cultivars into mainstream production, into organic agriculture or as “niche” crops, or to develop new varieties with high levels of diversity. Participatory approaches to plant breeding may be employed using this approach. New user groups, beyond formal-sector plant breeders, may be established and there may be an increased demand for materials from genebanks.

**Use of dynamic locally adapted breeding populations.** Broad-based plant populations which are used as a source of material for plant breeding programmes, such as the Composite Cross II and Iowa stiff stalk maize populations may also be regarded as a kind of *in situ* conservation of locally adapted (enhanced) germplasm. Such “mass reservoirs”[99] of genes represent a very cheap and efficient way of maintaining useful alleles and allelic combinations which are readily available to breeders. “As enhanced germplasm has become more widely known and available, breeders have increasingly turned to such sources and away from traditional collections, in which variability is stored in a static state.”[100] However, since some allelic diversity will be lost in such a population, multiple populations in different environments will be needed.

■

## Annex 1-2 endnotes

[1] Maxted N, Guarino L and Dulloo ME (in press) Management and monitoring of *in-situ* reserve. In Maxted N, Ford Lloyd NV and Hawkes JG (eds.) *Plant genetic conservation: the* in situ *approach*, Chapter 10. Chapman & Hall, London.

[2] These species may be divided into three groups:

(a) species that are members of complex climax ecosystems, such as the moist tropical forest, where the interdependency between species makes it impossible to plant them individually in monocultures;

(b) species with seeds presenting fugacious germination or with seeds possessing dormancy which cannot be broken by known artificial methods;

(c) species that have highly specialized breeding systems, depending, for example, on a single species of insect, bird or bat for pollination which, in turn, is dependent on other components of the ecosystem.

[3] George Ayad (1995) personal communication, IPGRI, Rome.

[4] This is only possible if genetic erosion has not occurred in the region that may contain genes of interest.

[5] A survey of United Kingdom-based private-sector plant breeding companies has shown that many such companies go directly to the field when they need PGRFA. However, this is much less true of state-funded breeders who use *ex situ* collections more often. Toby Hodgkin (1995) personal communication, IPGRI, Rome.

[6] Yonezawa K (1985) A definition of the optimal allocation of effort in conservation of plant genetic resources - with application to sample size determination for field collection. *Euphytica,* 34:345-354.

[7] Hawkes JG (1980) *Crop genetic resources: field collection manual*. IBPGR and Eucarpia, 37pp.

[8] The standards state that 1,500 to 2,000 viable seeds is preferred.

[9] Porceddu E and Damania AB (1992) Sampling variation in genetic resources of seed crops: a review. *Genetic Resources and Crop Evolution,* 39:39-49.

[10] Jana S (1988) Collecting crop germplasm during exploration: bulk samples or individual plants? *Plant Genetic Resources Conservation Newsletter*, 24:5-7.

[11] Thomas TA (1981) Gene pool sampling in vegetatively propagated crops. In Mehra KL, Arora RK and Wadhim SR (eds.) *Plant exploration and collection*, p. 34-47. NBPGR Science Monograph No. 3, New Delhi, India.

[12] Sinha GC (1981) Gene pool sampling in tree crops. In Mehra KL, Arora RK and Wadhim SR (eds.) *Plant exploration and collection*, p. 27-33. NBPGR Science Monograph No. 3, New Delhi.

[13] Withers LA (1994) New technologies for the conservation of plant genetic resources. In *Proceedings of the International Crop Science Congress*, p. 429-435. Ames, Iowa, USA. Crop Science Society of America.

[14] Guarino L, Rao VR and Reid R (1995) Collecting plant genetic diversity: technical guidelines. CAB International, London, 748 pp.

[15] FAO (1993) Ex situ *storage of seeds, pollen and* in vitro *cultures of perennial woody plants*. FAO Forestry Paper No. 113. 83 pp.

[16] Ellis RE, Hong T and Roberts EH (1990) An intermediate category of seed storage behaviour? I. Coffee. *Journal of Experimental Botany,* 41:1167-1174.

[17] Hong TD, Linington S and Ellis RH (1996) *Compendium of information on seed storage behaviour*. IPGRI, Rome.

[18] Cromarty AS, Ellis RH and Roberts EH (1995) *The design of seed storage facilities for genetic conservation*. IBPGR Handbook for Genebank No. 1, Rome, 96 pp.

[19] Delouche JC (1980) *Preceptos para el almacenamiento de semillas*. CIAT, Colombia. (mimeograph)

[20] Ellis RH, Hong TD and Roberts EH (1985) *Handbook of Seed Technology for Genebanks. Vol I. Principles and Methology.* IBPGR, Rome. 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.

[21] FAO/IPGRI (1994) *Genebank Standards*. Rome, 13 pp.

[22] 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 to 20 years.

[23] However a duplicate set of accessions was maintained by COPERSUCAR in Brazil; Comstock JC, Schnell RJ and Miller JD (1995) *Current status of the World Sugarcane Germplasm Collection in Florida*. Paper presented to International Workshop on Sugarcane Germplasm Conservation and Exchange, 28-30 June 1995, Brisbane, Queensland, Australia.

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

[25] If/when the viability of cryopreserved samples declines or a greater number of individuals are needed for evaluation purposes, the accession will be regenerated by somatic embryogenesis technology.

[26] Withers LA (1990) Cryporeservation of plant cells. *Biological Journal of the Linnean Society,* 43:31-42.

[27] Stanwood PC and Bass LN (1981) Seed germplasm preservation using liquid nitrogen (-196°C). *Seed Technology,* 5:26-31.

[28] Charrier et al (1991) in Rao and Riley.

[29] Marin ML, Mafla G, Roca WM and Withers LA (1990) Cryopreservation of cassava zygotic embryos and whole seeds in liquid nitrogen. *Cryo-Letters*, 11:257-264.

[30] Paulet F, Engelmann F and Glasczmann JC (1993) Cryopreservation of apices of *in vitro* plantlets of sugarcane (*Saccharum* sp.) hybrids using encapsulation/dehydration. *Plant Cell* Rep. 12:525-529.

[31] Withers LA (1991) Crop strategies for roots and tubers: potato a model for refinement, yam - a problem for development. In Becker B (ed.) *ATSAF/IBPGR Workshop on Conservation of Plant Genetic Resources*, p. 11-14. ATSAF/IBPGR., Bonn.

[32] Withers LA and Engels JMM (1990) The test tube genebank - a safe alternative to field conservation. *IBPGR NL for Asia and the Pacific*, 3:1-2.

[33] Op. cit., endnote 31.

[34] 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.

[35] 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.

[36] Dodds JH, Huaman Z and Lizarraga R (1991) Potato germplasm conservation. In Dodds JH (ed.) In vitro *methods for conservation of plant genetic resources*, p. 93-109. Chapman and Hall, London.

[37] Kuo CG (1991) Conservation and distribution of sweet potato germplasm. In Dodds JH (ed.) In vitro *methods for conservation of plant genetic resources*, p. 123-148. Chapman and Hall, London.

[38] Novak FJ (1990) Allium tissue cultures. In Rabinocitch JL and Brewster JL (eds.) *Onion and allied crops*, p. 233-250. CRC Press Inc., Florida, USA.

[39] FAO (1994) CPGR-Ex1/94/5.

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

[41] Redenbaugh K (ed.) (1993) *Synseed: applications of synthetic seeds to crop improvement*. CRC Press, London.

[42] Hong TD and Ellis RH (1996) *A protocol to determine seed storage behaviour*. IPGRI Publication, Rome; Tao K-L, Zheng G-H and Cheng H-Y (1995) *An overview of ultra-dry seed storage for germplasm conservation*. FAO; Rome, 10 pp.

[43] Matlick JS, Ablett EM and Edmonson DL (1992) The gene library-preservation and analysis of genetic diversity in Australasia. In Adams RP and Adams JE (eds.) *Conservation of plant genes. DNA Banking and* in vitro *Biotechnologies*, p. 15-35. Academic Press, San Diego, California, USA.

[44] CPGR (1995) *A preliminary abstract of a current study on* ex situ *collections at botanic gardens with particular emphasis on plant genetic resources for food and agriculture*. CPGR-6/95/INF.10.

[45] Op. cit., endnote 21.

[46] The terms "base collection" and "active collection" are not synonymous with the conditions under which the seeds are stored. However, in order to preserve base collections it is usual to maintain such collections under long-term seed storage conditions.

[47] Brown AHD (1989) The case for core collections. In *The use of plant genetic resources, p. 136-156.* Cambridge University Press, Cambridge, UK.

[48] See for instance Van Hintum TJL (1994) *Drowning in the gene pool*. Section III, p. 1-8. Swedish University of Agricultural Sciences, Svalov, Sweden. (Ph.D. thesis)

[49] It is worth noting that multiplication is a different term to describe an activity that is associated with supplying seed samples from an active collection and replenishing the active collection stocks to meet demands from users, rather than regenerating to replenish stocks for a collection as viability declines.

[50] 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*. IBPGR, Rome.

[51] Frywell PA (1957) Mode of reproduction of higher plants. *Botanical Review*, 23:235-230.

[52] Porceddu E and Jenkins G (eds.) *Seed regeneration of cross-pollinated species*. AA Balkema, Rotterdam, the Netherlands.

[53] USDA estimates that regeneration costs can vary between USò50 and ò500 per accession depending on whether the accession is self-pollinated or insect cross-pollinated. However, such costs also vary regionally depending on labour costs and other factors. For instance, it is estimated that it may cost USò700 to regenerate a cabbage accession in the United States, while in China it might cost ò15 to regenerate the same accession, and even less in Ethiopia.

[54] Free JB (1970) *Insect pollination of crops*. Academic Press, New York.

[55] 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.

[56] Moss H and Guarino L (1995) Gathering and recording data in the field. In Guarino L, Rao VR and Reid R (eds.) *Collecting plant genetic diversity: technical guidelines*, p. 367-417. CAB International, London.

[57] Kaiser WJ, Stanwood PC and Hanan RM (1989) Survival and pathogenicity of *Ascochyta fabae* f.sp. lentil in lentil seeds after storage for four years at 20 to 196°C. *Plant Disease,* 73:762-764.

[58] Hampton R, Waterworth H, Goodman RM and Lee R (1982) Importance in seed borne viruses in crop germplasm. *Plant Disease*, 66:977-978.

[59] Frison EA, Putter CAJ and Diekmann M (eds.) (1993) *FAO/IBPGR Technical Guidelines for the Safe Movement of Coconut Germplasm*. Rome, 48 pp. ISBN 92 9043 156 3.

[60] INBAB (1995) *Annual Report 1994.* Montpellier, France.

[61] Van Soest (1995) personal communication, Wageningen, the Netherlands.

[62] FAO/IBPGR (1993) *Technical Guidelines for the Safe Movement of Germplasm*. Rome.

[63] Ng SYC, Thottapilly G and Rossel HW (1992) Tissue culture in disease elimination and micropropagation, In Thottapilly G, Monti LM, Mohan Raj DR and Moore AW (eds.) *Biotechnology: enhancing research on tropical crops in Africa*.
p. 171-182. Technical Center for Agriculture and Rural Cooperation (CTA), Wageningen.

[64] Maxted N, van Slagaren MW and Rihan JR (1995) Ecogeographic surveys. In Guarino L, Ramanatha Rao V and Reid R (eds.) *Collecting plant genetic diversity technical guidelines*. CAB International, London.

[65] The lack of accurate ecogeographic surveying of many wild relatives of crop plants has contributed to many genebanks having extremely asymmetric collections, i.e. they have many accessions of the cultivated gene pool from a limited number of geographic areas and only a small number of accessions from many areas and many related subspecies or species. Hence, the genetic diversity in most genebanks is not representative of the gene pool of the crop in question.

[66] 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. 27 pp.

[67] IUCN (1994) *IUCN Red List Categories*. Gland, Switzerland, 21 pp.

[68] Estimation of effective population on the basis of ability to withstand loss of genetic variability owing to small population size; on the basis of the number required to maintain the evolutionary potential of the population; or calculating population size that will minimize the sampling loss of alleles that occurs in low frequency.

[69] Daily GC (1995) Restoring value to the worlds degraded lands. *Science,* 269:350-353.

[70] Jordan WR (1988) Ecological restoration: reflections on a half-century of experience at the University of Wisconsin-Arboretum. In Wilson EO (ed.) *Biodiversity*, p. 311-316. National Academy Press; Washington, DC.

[71] IUCN (1994) *Guidelines for Protected Area Management Categories*. Gland, Switzerland, 261 pp.

[72] di Castri F and Younes T (1990) Fonction de la biodiversité au sein de l'ecosystème. Compte rendu resumé d'une réunion de travail de l'U.I.S.B - SCOPE, 29-30 juin 1989, Washington. *Acta Oecologica,* 11:429-444.

[73] Op. cit., endnote 66.

[74] Akeroyd J (1995) How to reintroduce a plant successfully. *Plant Talk*, July 1995.

[75] Hoyt E (1988) *Conserving the wild relatives of crops*. IBPGR, Rome.

[76] FAO (1989) *Plant genetic resources.* Rome.

[77] Jain SK (1975) Genetic reserves. In Frankel OH and Hawkes JG (eds.) *Crop genetic resources for today and tomorrow*, p. 379-398. Cambridge University Press, New York.

[78] Halffter G (1994) Putting the biosphere reserve concept into practice: the Mexican experience. In UNESCO *Integrating conservation, development and research.* Parthenion Publishing, London.

[79] Pimbert MP and Pretty JN (1995) *Parks, people and professionals: putting "participation into protected area management*". Discussion Paper No. 57, UNRISD, Geneva.

[80] Colchester M (1992) *Sustaining the forests: the community-based approach in South and Southeast Asia*. Discussion Paper No. 35, UNRISD, Geneva.

[81] Wells MP and Brandon K (1992) *People and parks linking protected area management with local communities*. World Bank / WWF / USAID / Washington, DC.

[82] Gilles JL (1988) Slippery grazing rights: using indigenous knowledge for pastoral development. In Whitehead EE and Hutchinson CF (eds.) *Arid lands: today and tomorrow*. Proceedings of an International Research and Development Conference, 20-25 October 1995, Tucson, Arizona, USA. Belhaven Press, London.

[83] Conant (1989) The Pokot way with thorny shrubs: a case example. In McKell CM (ed.) *The biology and utilization of shrubs*, p. 593-602. Academic Press, London.

[84] Op. cit., endnote 71.

[85] Ghimere K and Pimbert MP (1996) *Social change and conservation*. UNRISD and Earthscan, UK; op. cit., endnote 79.

[86] Op.cit., endnote 79.

[87] Robertson J (1992) Biosphere reserves: relations with Natural World Heritage sites. *Parks,* 3:29-34.

[88] Op. cit., endnote 1.

[89] World Heritage Sites are protected areas designated under the Convention Concerning the Protection of the World Cultural and Natural Heritage adopted by the General Conference of UNESCO in 1972. They are defined by the Convention as having outstanding value for all humanity.

[90] Ramsar sites are wetland sites of world importance designated under the Convention on Wetlands of International Importance, signed in Ramsar, Islamic Republic of Iran in 1971.

[91] IUCN (1994) *Guidelines for protected area management categories*. CNPPA with the assistance of WCMC. IUCN, Gland, Switzerland and Cambridge, UK. 261 pp.

[92] IUCN (1995) Social Policy Unit.

[93] Iltis HH, Doebley JF, Guzman R and Pazy B (1979) *Zea diploperennis* (Graminae): A new teosinte from Mexico. *Science,* 203:186-188.

[94] Worede M (1993) *The role of Ethiopian farmers in the conservation and utilization of crop genetic resources*. International Crop Science I. Crop Science Society of America, Madison, Wisconsin, USA.

[95] 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.

[96] Montecinos C (1994) Bringing farmer and non-farmer breeders together. *Seedling*, December 1994, GRAIN, Barcelona, Spain.

[97] Vicente PR (1994) The MASIPAG program: an integrated approach to genetic conservation and use. In *Growing diversity in Farmers Fields*. Proceedings of a Regional Seminar for Nordic Development Cooperation Agencies, 26-28 September 1993, Lidingo, Sweden.

[98] Seville, Spain, March 1995.

[99] Simmonds, NW (1962) Variability in crop plants: its use and conservation. *Biological Reviews*, 37:422-465.

[100] National Research Council (1993) *Managing Global Genetic Resources*, p. 186. National Academy Press, Washington, DC.

# ANNEX 1-3
# Methods for Utilization of PGRFA through Plant Breeding

## A1-3.1 INTRODUCTION

Plant breeding has four fundamental steps (Figure A1.2):

a) Goal setting. Goals are set taking account of economic and biological factors, and then methodologies are selected.

b) Generating new diversity. Sufficient genetic variability must be available for a trait or crop to be improved. If necessary, the genetic base of the breeders' gene pools can be widened through introgression of single genes or traits or by a large-scale infusion of new germplasm through base-broadening.

c) Selection. The improvement of a trait or crop is achieved through selection, the response being determined by the genetic variability present. The selection methods used in plant breeding differ between inbreeding, crossbreeding and vegetatively propagated crops.

d) Cultivar release. The improved cultivar is released and marketed.

The following sections consider each of these steps in turn. Participatory approaches to plant breeding are also considered.

## The breeding cycle

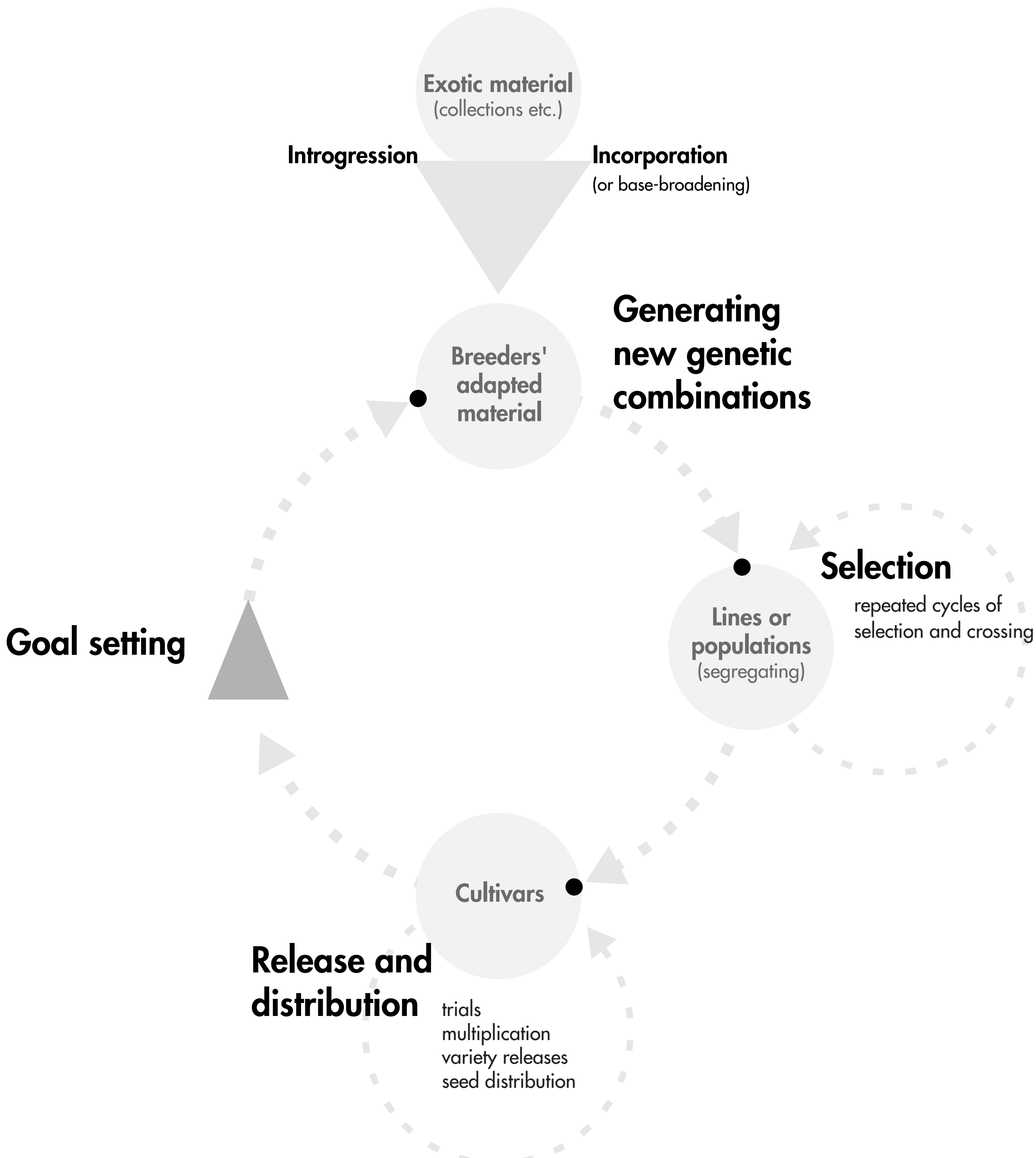



Figure A1.2

## A1-3.2 PLANT BREEDING: GOAL SETTING

All plant breeding programmes have the same ultimate objective; to improve or maintain yield and quality characteristics in order to produce varieties attractive to farmers or other end-users (i.e. processors and/or consumers), within biologically or environmentally imposed limitations. It is important, therefore, that the process of goal-setting be demand driven. Consideration might also be given to matters related to the deployment of genetic resources, such as the need to reduce genetic vulnerability. Another breeding goal is resistance to environmental extremes. These include pests and diseases, heat, cold, drought, excess moisture and extremes of soil type.

The breeding methods chosen will, at least in part, be determined by the goals. The choice between breeding plan (e.g. hybrids versus synthetics/composites) will depend on the type of market being sought for the final cultivar (e.g. for commercial or subsistence farmers; for high-production or marginal areas). In addition, a goal requiring the genetic base to be widened by introgression or incorporation will determine whether or not exotic material is required.

The breeder may also consider whether a wide-adaptation or specific adaptation approach should be followed, and whether farmer participatory methods should be employed.

## A1-3.3 PLANT BREEDING: GENERATING NEW COMBINATIONS

The choice of parental material for crossing is the first practical step in generating new combinations of genes and new varieties. Usually the basis of a breeding programme is the breeders' working populations which are already well adapted to the intended environment. However, exotic genetic material may also be required. As discussed elsewhere, the establishment of improved working populations is an expensive and usually precompetitive activity, from a commercial perspective.

Molecular markers which densely cover an entire crop genome (e.g. several hundred marker loci), preferably at roughly equal intervals, can be used to develop a molecular map for a crop, which can then be used to determine linkage between a specific molecular marker and a strongly heritable trait.[1] This represents a major advance for plant breeding as many traits are difficult to select for directly from breeding populations. Nevertheless, due to the considerable research and expense involved in establishing molecular maps for crop species, most of the maps currently under development are for crops of major commercial importance. As yet, little attention has been given to establishing genetic maps (Table A1.7) for crops which are important to developing countries in terms of food security, but have little or no importance on international markets, i.e. orphan food crops.

**Complexity and costs of plant biotechnology and breeding techniques**

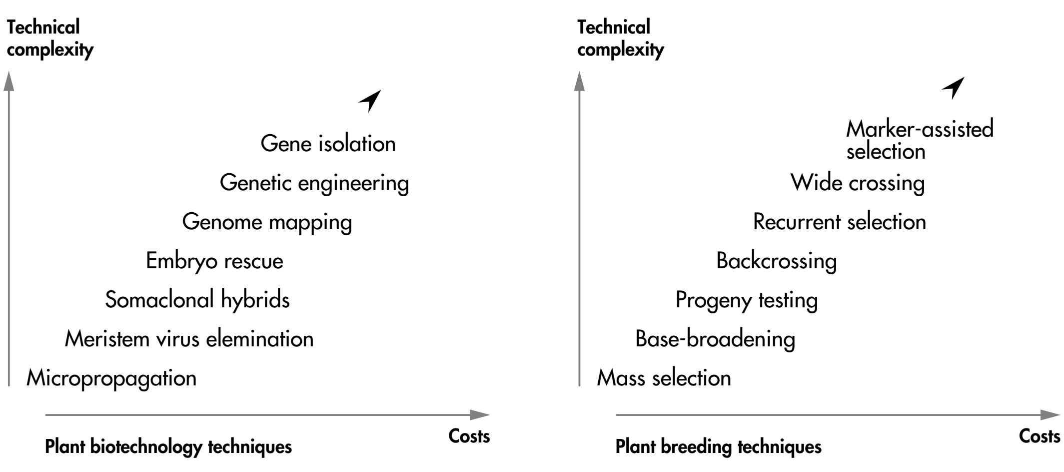



Figure A1.3

The use of molecular markers for introgression in breeding programmes may also be prohibitively expensive. The cost of scoring molecular markers in the early 1990s was 100 to 1,000 times as expensive as measuring standard phenotypes in most crops.[2] At present it is easier to map simple qualitative traits than multigenic or quantitative traits[3] although rapid advances are being made in the development of the technologies[4] and analytical techniques[5] needed for mapping quantitative trait loci (QTL).

**Table A1.7 List of some plant species for which genome mapping projects are under way**[6]

| Plant species | | | | |
|---|---|---|---|---|
| Alfalfa | Celery | Lentil | Pepper | Spruce |
| Almond | Cereal | Lettuce | Pine | Squash |
| Apple | Chrysanthemum | *Lilium* | Plum | Sugar cane |
| Arabidopsis | Citrus | Melon | Poplar | Sunflower |
| Asparagus | Clover | Oat | Potato | Tobacco |
| Barley | Cocoa | Onion | Rice | Tomato |
| Bean | Maize | Papaya | Rose | Turf grass |
| Berry | Cotton | Pea | Rye | Wheat |
| Brassica | Cucumber | Peach | Snapdragon | |
| Cabbage | Cuphea | Peanut | Sorghum | |
| Carrot | Grasses | Pear | Soybean | |

Many qualitative and some quantitative trait loci have been recently mapped using molecular markers. These include loci that account for vertical and horizontal disease resistance, yield, photoperiodicity and other agronomic traits (Table A1.8).

**Table A1.8 Some qualitative and quantitative traits which have been mapped using molecular markers**[7]

| Trait | Crop | Reference |
|---|---|---|
| Resistance to *Phytophthora infestans* | Potato | Leonardsschippers *et al.*, 1994 |
| Photoperiod response | Barley | Laurie *et al.*, 1994 |
| Resistance to *Helminthosporium turcicum* | Maize | Freymark *et al.*, 1994 |
| Resistance to leaf and stem rust | *Triticum*/Wheat | Innes and Kerber, 1994 |
| Resistance to *Cladosporium fulvum* | Tomato | Balinkurti *et al.*, 1994 |
| Grain yield components | Maize | Veldboom and Lee, 1994 |
| Resistance to root-knot nematode | Tomato[8] | Klein-Lankhorst *et al.*, 1991 |
| Resistance to downy mildew | Lettuce | Paran and Michelmore, 1993 |

Genome sequencing projects are expected to produce much basic information about specific genes and their effects in agriculture, allowing for better utilization. Again, it is important to note that realization of benefits from such technologies depends on the continued conservation and availability of the biological resources. Investments in technology development should be made hand-in-hand with investment to protect the resource base.

Many of these agronomic traits have considerable value and a large research investment is currently being made in developing genetic maps of commercial crops and linking molecular markers to economically important traits for introgression and/or gene isolation.

### Wide crosses

Sometimes the desired exotic material is of a different species, for example, of a wild relative of the crop species in question, and "wide crosses" are necessary. In such cases, problems of sexual incompatibility may arise, leading to hybrid sterility or lack of genetic recombination. A number of techniques have been developed to overcome such biological barriers,[9] including:

- *embryo rescue*: an otherwise non-viable hybrid embryo is transferred to a culture medium where viable plants may be regenerated and backcrossed to the cultivated species to introduce the desired genetic trait. Some examples of successful wide crosses using this technique include the interspecific hybrids between *Lycopersicon esculentum* and *L. peruvianum*[10] or *Medicago sativa* and *M. rupestris*;[11]
- *protoplast fusion*: the asexual fusion of somatic cells *in vitro,* followed by regeneration of hybrid plants. In *Brassica napus* (rapeseed), a unique "hybrid" has been produced containing rapeseed chloroplast and nuclear DNA and radish mitochondrial DNA.[12] This holds great promise as a male-sterile cytoplasm for F1-hybrids in rapeseed.

Using the techniques described above, it is possible, although time-consuming and expensive, to transfer genes from wild relatives into the cultivated gene pool.[13] For instance, there has been great success in wide crossing of related species with wheat in the past 12 years. Since 1983[14] wheat (*Triticum aestivum)* has been successfully crossed with at least eight different species[15] and crosses of wheat with species such as oat, maize, sorghum, *Tripsacum, Teosinte*, rice and pearl millet have been carried out.[16] Other extremely wide crosses include oat x maize and rice x pearl millet. It is considered to be an open question just how wide a cross between related plant species can be.[17] Wide crossing is an interdisciplinary research area which warrants international cooperation between researchers and further research attention.[18] However, genetic transformation technology (as discussed in the next section) also offers alternatives for the introgression of traits between different species.

### Gene transformation

Genetic engineering has tremendous potential to increase the gene pool available for use in agricultural crops. Not only can genes for traditional agronomic traits be transferred, but also previously inaccessible genes from virtually any species, whether plant, animal or bacteria. Indeed, by extending the gene pool available for plant improvement to all species, genetic engineering challenges and, to some extent, broadens the very concept of what PRGFA are.

Plant genetic transformation describes the transfer of specific genetic material from any species into a plant genome. Two main techniques are involved: the use of a disarmed form of the plant pathogenic bacterium called *Agrobacterium tumefaciens* as a biological vector and the use of "gene guns" to insert genes via DNA-coated microparticles.[19]

Since the first transgenic plants of tobacco[20] were produced in 1984, it has now become possible genetically to transform an ever expanding range of plant species. At least sixty different plant species are now reported to have been engineered genetically for a wide variety of useful characteristics.[21] Other recent developments in transgenic plant technology include the genetic transformation of the chloroplast genome[22] allowing higher levels of gene products to be obtained, and the development of antisense[23] and gene silencing[24] techniques to 'turn off' undesirable genes whose DNA sequences are known.

Many useful transgenic phenotypes have been developed using genes from other plant species. Techniques for identifying and isolating desirable genes from plants are currently more labour-intensive than gene transfer techniques. For this reason, few agronomically useful genes from crop and plant gene pools are currently available for transfer. However, improvements in gene mapping techniques continue, particularly for the isolation and cloning of many single genes which have strong heritability[25] (e.g. the *Fca* gene responsible for vernalization.[26])

More than 12 plant resistance genes[27] to pathogens have been isolated since the first resistance gene was isolated (*HM1*) in 1992 (Table A1.9). Detailed review of these techniques and results can be found in the scientific literature.[28]

**Table A1.9 Some plant resistance genes to pathogens that have been isolated and cloned since 1992**[29]

| Plant pathogen or disease | Resistance gene | Crop or plant species | Reference |
|---|---|---|---|
| *Cochliobolus carbonum* | HM1 | Maize | Johal and Briggs, 1992 |
| *Pseudomonas syringae* | Pto | Tomato | Martin *et al.*, 1993 |
| *Pseudomonas syringae* | RPS2 | *Arabidopsis thaliana* | Mindrinos *et al.*, 1994; Bent *et al.*, 1994 |
| Tobacco mosaic virus | N | Tobacco | Whitham *et al.*, 1994 |
| Flax rust | L6 | Flax | Lawrence *et al.*, 1994 |
| *Cladosporium fulvum* | Cf9 | Tomato | Jones *et al.*, 1994 |
| *Cladosporium fulvum* | Cf2 | Tomato | Dixon *et al.*, in press[30] |

Non-plant sources of genes can also be used. Some of the many reported applications include the development of insect-resistant transgenic plants using the *Bacillus thuringiensis* (Bt) gene[31] or the use of transgenic plants as factories[32] (molecular farming) for the production of valuable compounds such as natural plastics, novel carbohydrates, speciality vegetable oils, pharmaceuticals or vaccines, nutraceuticals and enzymes. Bacterial genes have also been used to produce a system for developing male-sterile transgenic plants of any species,[33] in which the male sterility can easily be switched on and off.[34] This development is expected to be useful for breeding hybrids of any crop for which there are currently no male-sterile lines. Other transgenic plants currently under development include those with altered oil constituent levels,[35] higher nutritional value, non-allergenicity, improved mineral uptake, altered lignin content, novel flower colour, extended post- harvest storage or quality, cold, drought and salinity tolerance and resistance to viruses, bacteria, fungi, nematodes and insects.[36]

Current genetic engineering techniques are limited to the transfer of individual genes or small regions of genomes (mainly qualitative traits). Thus, for the foreseeable 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). Polygenic agronomic traits cannot at present be transferred by genetic engineering.

### A1-3.3.2 Incorporation

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 selecting the resulting population over a large number of generations in the target environment(s) of the breeding programme (or under similar conditions). This is known as *recurrent selection* (RS). The final population might be used directly in the breeding programme, or first crossed with other locally adapted material.

The simplest incorporation programme uses natural selection to adapt diverse germplasm to local conditions. This was the method used to produce Harlan's "Composite Cross II" of barley which was made by crossing 28 cultivars from the world collection in all combinations, followed by 60 generations of selection in California.

The process can be accelerated by using conscious selection. The basic distinction is between "phenotypic" and "genotypic" RS. In "mass" selection of desirable phenotypes, seeds are harvested on the selected plants only. It is better, however, if the undesirable types can be removed prior to flowering, so that only the selected plants contribute their genes. Phenotypic RS methods have been used very successfully for "incorporation" in the potato, enabling breeders to renew the crop fundamentally. In 1960 United Kingdom potato breeders decided to "recreate" the very narrow European "tuberosum" gene pool from "andigena" stocks.[37] By 1970, spectacular progress had been made. The success of the effort was due to the fact that andigena potatoes have been well collected and characterized and that there was strong support for the project both from researchers and from funding agencies.

Phenotypic RS methods have the advantage of being inexpensive. They are often successful in improving highly heritable traits like disease resistance and adaptation, and in removing off-types. However, for improving yield or other low-heritability traits, progeny testing is required to determine the value of the genotype. The Iowa Stiff Stalk Synthetic of maize, which is the source of the most popular United States Corn Belt inbred lines, was developed in this way.[38]

Some of the assumptions behind and approaches to incorporation can be summarized as follows:[39]

- The objective of incorporation is to broaden the genetic base of a crop by adding a wide range of new parents. It should be done on a large scale because there will be heavy losses and discards.
- Exotic materials must be included, although their breeding worth may not be known beforehand.
- The level of conscious intervention by the breeder will vary widely, from little (semi-natural selection, mass selection) to a great deal (controlled polycrosses).
- Since the programme will start with materials of questionable quality, there will be a need for extensive recombination.
- Several generations will be required to achieve substantial progress, implying years of effort.
- The outcome of the programme will be characterized by enhanced variation and increased and sustained response to selection.

## A1-3.4 PLANT BREEDING: SELECTION

Four basic breeding populations determined by mating and propagation systems may be identified: inbred lines, open-pollinated populations, hybrids, and clones (Table A1.10).

**Table A1.10 Populations and breeding methods**

| Population type | Crop characteristics: • mating system, • life cycle, • propagation | Crossing and selection methods | Genetic characteristics |
|---|---|---|---|
| **Inbred lines** | Inbreeding<br>Annual<br>Seed-propagated | Selfing | Homogeneous<br>Homozygous |
| **Open-pollinated populations** | Outbreeding<br>Annual<br>Seed-propagated | Population improvement or synthetics | Heterogeneous<br>Heterozygous |
| **F1 Hybrids** | Outbreeding<br>Annual or biennial<br>Seed-propagated | Crossing of inbred lines | Homogeneous<br>highly heterozygous |
| **Clones** | Outbreeding<br>Perennial/quasi-annual<br>Vegetative | Selection among clonal propagules | Homogeneous<br>Heterozygous |

*Source*: Adapted from Simmonds (1979)

### A1-3.4.1 Selection procedures for inbred pure lines

Inbred pure lines are homogeneous and homozygous genotypes. They are most easily developed in inbreeding crops but can also be developed in outbreeding crops that are not self-incompatible. Pure line selection has been practised in the past even by enterprising farmers developing distinct inbred lines from their landraces.[40] These lines are isolated by the selection of desirable segregates in F2 - F7 generations of crosses between parental materials.

Three basic techniques are used in developing inbred pure lines:

- **Pedigree System**. Single plant selection is practised up to near-homozygosity. Selection is started in the early segregating generations when heterozygosity is high. This method is very effective for highly heritable traits.
- **Bulk Breeding Systems**. The F2 and succeeding generations are grown in bulk before making single plant selections. In early generations, selection is restricted to characters which are highly heritable and easily handled such as stature, seed size and some disease resistances.
- **Single Seed Descent**. Single seed is taken from each plant without practising any selection.

### A1-3.4.2 Selection procedures for open-pollinated populations

Open-pollinated populations may be modified by changing gene frequencies through recurrent selection and can be constructed by making synthetics via parental lines or clones.

- **Population improvement methods.** The objective of these methods is to increase the gene frequency of favourable alleles while maintaining genetic variability. Population improvement methods fall into two groups:
  - **Mass selection.** is based on purely phenotypic selection.
  - Selection with **progeny testing** allows elucidation of characters not shown phenotypically.
- **Synthetic varieties.** These varieties are regularly reconstructed from parents. Some authors use "synthetic" to describe any open-pollinated variety constructed from combining lines or clones and propagated indefinitely without recourse to parental stocks. Here it applies to randomly mated experimental populations reconstructed from selected parental lines or clones.

### A1-3.4.3 Selection procedures for hybrid varieties

Hybrids are homogeneous and highly heterozygous genotypes (usually produced in the outbreeding crops). They are constructed by crossing complementary inbred lines selected for combining ability (See Box A1.8). Use of apomixis may allow the heterozygosity of F1 hybrids to be fixed in subsequent generations (Box A1.9).

### A1-3.4.4 Selection procedures for clones

Clonal crops have homogeneous and heterozygous genotypes, usually produced in the outbreeding plant species. They are isolated by selection of desirable clones in subsequent vegetative generations from the F1 population between heterozygous parental clones.

## Box A1.8 F1 hybrids or synthetic and composite populations?

For many out-crossing crops, such as maize, two main approaches to breeding are possible: development of composite or synthetic populations; or development of F1 Hybrids.

Hybrids generally have a higher yield potential, of 15% to 20%, over the open-pollinated varieties (OPVs) and are thus in high demand. The uniformity of F1 hybrids helps in mechanical harvesting, marketing and varietal identification. Moreover, F1 hybrids have a built-in protection against reuse of saved seed, which makes them attractive to commercial companies. The resultant F2 populations are not uniform and generally yield less. About 40% of the global commercial seed business is in hybrids. In several countries, the establishment of hybrid production industries has stimulated private initiatives in breeding, seed production and distribution. However there are a number of factors that limit the advantages of hybrids:

- The use of hybrids requires a relatively well-developed capacity for plant breeding and a well-organized seed multiplication and distribution system. To be successful, it is important to ensure that a stable and sufficient supply of hybrid seeds reaches the farmers before the optimal planting time. As farmers become more dependent on external seed deliveries (as well as on the markets for selling their products), they become vulnerable if such services are not maintained.
- The uniformity of F1 hybrids may lead to vulnerability to biotic and abiotic stresses.
- On-farm seed saving is practically impossible without loss of the hybrids' superior qualities, forcing the grower to purchase new seed every season. While this has advantages in providing incentives to breeders and seed companies, it is often not appropriate for resource-poor farmers. They will only purchase hybrid seed if their yield advantage is sufficient to cover the extra cost.
- It has been argued that OPVs may reach the same yield level as F1 hybrids given a long-term selection effort. There are fewer commercial incentives at present for such an approach as compared with development of hybrids.

Because of the limitations of hybrids for resource-poor farmers, and because the private sector is so active in producing them, the International Agricultural Research Centres (IARCs) allocate only a small fraction of their budget towards hybrid development. For example: IRRI spends 10% of its research and development (R&D) budget for its irrigated rice programme on hybrid rice, compared to 30% on the development of pure lines; CIMMYT spends 18% of its maize programme funds on hybrids; AVRDC spends 20% of its breeding budget for various crops on hybrids; CIAT does not conduct any research on hybrids in rice and beans.

**Box A1.9 Apomixis**

The development of apomictic[41] crop varieties is one example of plant breeding research aimed at reducing external inputs while maintaining or increasing yields. Apomixis is a genetically determined trait, whereby certain plants produce seeds asexually. In an agricultural context, apomixis has the potential to fix clonally the characteristics of particularly well adapted cultivars - including hybrids - from generation to generation, while maintaining heterosis. This is not possible with sexual seeds. Progress is being made in developing apomictic food crops, such as maize and millet, by introgressing apomictic traits from wild relatives.[42] The Hunan Hybrid Rice Research Centre in China is seeking to identify sources of apomictic rice germplasm. Progress in the isolation of apomictic genes for future direct transfer into crops without apomictic wild relatives, by genetic engineering, has also been reported.[43] This approach, if successful, would allow farmers and breeders to select seeds of the most productive hybrid varieties for replanting without losing hybrid vigour.

## A1-3.5 PLANT BREEDING: RELEASE AND DISTRIBUTION

The ultimate goal of plant breeding is to place genotypes with superior performance in farmers' fields. 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 breeder's own trials usually take at least three seasons and are followed by trials, including on-farm trials, carried out by others. The data from trials are also used for registration (varietal registration and PBRs) and recommendations of the varieties to the farmers. The discrepancy between conditions on testing sites and on-farm conditions can be an issue of concern in some cases.

## A1-3.6 PARTICIPATORY PLANT BREEDING[44]

The observation that breeders and farmers sometimes differ in their evaluations of crop varieties has led to the development of more participatory approaches to plant breeding. The rationale for employing participatory plant breeding has been described in Chapter Four (Utilization). Participatory plant breeding is defined in its broadest sense, ranging from plant breeder-controlled decentralized breeding to various degrees of farmer involvement in the breeding or improvement process.

"Informal" crop improvement by farmers and "formal" plant breeding by professionals in companies and research institutes are, despite some fundamental similarities, different systems. Participatory approaches draw upon the comparative advantages of both (Table A1.11).[45] Professional plant breeders carry out germplasm enhancement in much the same way they would if they were working alone but the final selection and variety testing is done by farmers, or by breeders and farmers working together (Tables A1.12 and A1.13).

**Table A1.11 Comparison of formal-sector and farmer-based plant breeding**

| | Conventional plant breeding | Farmers' plant breeding |
|---|---|---|
| Plant breeding methods employed | Several, including crossbreeding, hybridization and gene technology | Predominantly mass selection |
| Multiplication methods | Conventional on-farm, and through cell and tissue culture | Conventional on-farm |
| Sources of new variation | Worldwide, from induced mutations and potentially from unrelated species | Farmer-farmer exchange and introgression from wild relatives |
| Taxonomy and knowledge | Scientific taxonomy, little knowledge on uses | Utilitarian taxonomy, backed up by traditional knowledge |
| **Results** | | |
| Varieties produced | Small number of uniform varieties selected for wide adaptation | Large number of landraces with inherent variation selected for local adaptation |
| Yield potential | High in good environments | Moderate or low |
| Time-span for production of variety | 10 to 20 years | Continuous with production |

*Source*: Adapted from Berg T, Bjornstad A, Fowler C and Skroppa T (1991)

Participatory approaches are not new. They have long been used in animal breeding, where they have proved to be not only feasible but often superior to more formal systems. Breeding is in the hands of the farmer, who is often able to make use of modern tools such as artificial insemination and computerized recording of animal performance. In the nineteenth century and early twentieth century, the United States actively promoted farm-level crop diversity by sending millions of seed samples of described but untested varieties to farmers who performed on-farm research and selection to produce a huge number of crop varieties.[46]

Recently, there has been an increased interest in participatory plant breeding.[47] Table A1.12 summarizes a number of case studies. Participatory breeding can be applied to a wide range of crops, can utilize both local and improved materials in crosses, and can promote increased interaction between farmers and breeders.

**Table A1.12 Case studies of participatory plant breeding**

| Country | Species | Mating system | Sources of variation | Selection | | Product | Researcher |
|---|---|---|---|---|---|---|---|
| Syrian Arab Rep. | Barley | sp | LLR | Lines | OF RM | Pure lines of LR | Ceccerelli and Grando |
| Syrian Arab Rep. | Barley | sp | LLR x LR | Seg. pop. | OS RM OF | Advanced populations | Ceccerelli and Grando |
| Rwanda | Beans | sp | LLR x MV | Lines | OS FEval | Many lines in mixtures | Sperling |
| Brazil | Beans | sp | LLR x LR x MV | Seg. pop. | OS FEval OF FEval | 1 ->formal n ->inf | Zimmerman |
| Peru | Potato etc. | cl | LLR and MV | Clones | OF FM | Clones in mixtures | Holle |
| India | Pearl millet | op | LLR x LR xMV | Population | OF FEval OS FSele | Improved pop. | Weltzein |
| Nepal | Rice | sp | LR x MV | Seg. pop. | OF RM | 1->formal; n->inf | Witcombe |
| India | Maize | op | LR x MV | Composite | OF FEval | Population | Witcombe |
| India | Various | op/sp | MV (released) | Varieties | OF FEval | MV | Witcombe |
| Colombia | Beans | sp | LR x MV | Seg. pop. | OS FEval OF FEval | 10 advanced lines | Kornegay |
| India | Rice | sp | LLR x LR x MV | Lines | OF F/RM | | Sarkarung |

Abbreviations: sp = self-pollinated; op = open-pollinated; cl = clonal
LLR = local landrace; LR = landrace; MV = modern or introduced material
OF = on-farm; OS = on-station; RM = researcher-managed; FEval = farmer-evaluated

*Source*: Adapted from Hardon (1995)

Studies on participatory plant breeding[48] (Table A1.12) have indicated that:

- farmers carry out experiments and monitor and evaluate progress;
- there are almost always farmers within communities with specialized knowledge and skills in seed production and selection; often these farmers are women;

- farmers are very good at evaluating planting materials in terms of local adaptation;
- farmers actively manage mixtures of seeds (e.g., beans in Rwanda, potatoes in Peru).

Participatory approaches can be used at various stages in the breeding cycle (Figure A1.2). The point at which such an approach might be utilized will be determined by the objectives of the breeding programme, the target environment, the strength of the farmer/community system and the attitudes of the institutional system. The participatory approach, then, is really a continuum ranging from breeder-controlled to farmer-controlled processes.

Above all, this system requires cooperation between breeders and farmers in partnership (Table A1.13). The first step is likely to involve identifying local farmers and farm families, who are reliable and experienced in managing specific crops. Women are often key to the effort.[49] Once the goals have been set, plant breeders will probably play the major role in developing new breeding populations, involving both local materials and material from other sources. They will seek to widen the genetic diversity of the target crop through controlled crosses and to add new characteristics while maintaining a reasonable level of local adaptation. For outcrossing species, introduction of new materials can also take place at the level of farmers through introgression.

**Table A1.13 Options for involvement of farmers and formal-sector breeders**

| Stage in breeding cycle | | Potential for role of: Farmers | Breeders | Observations |
|---|---|---|---|---|
| 1: Goal setting | | *** | *** | Need to identify farmers |
| 2: Generating new diversity | Germplasm enhancement | | *** | |
| | Identify sources of: | | | By farmers for out-crossers only |
| | • Specific adapation | ** | ** | |
| | • General adaptation (e.g. resistance) | | *** | |
| | • Crossing | * | *** | |
| 3: Selection | Segregating populations: | | | |
| | F2/F3 | * | *** | Issue of risk avoidance is important |
| | F4/F5 | ** | *** | |
| | Populations of lines | *** | ** | |
| | Finished lines/varieties | *** | * | |
| 4: Release and distribution | | *** | ** | |

*Source*: adapted from Hardon (1995)

Participatory approaches appear to have a number of advantages:

- They facilitate the identification and addressing of farmers' needs:
- They produce multiple heterogeneous varieties adapted to local conditions as opposed to the few uniform varieties with broad adaptability produced by the formal system:
- They can be faster. The formal system needs 10 to 20 years from the initiation of a breeding programme until the result is available to the farmer. Some of this time is used for the breeding itself, some for achieving uniformity and some for testing. The participatory system and the nature of its products mean that some steps taken by the formal system can be dropped and seed be made widely available.

There may also be a number of drawbacks and impediments to such approaches. Some breeders may legitimately or otherwise resist the added time and effort required to reach and interact with farmers. Breeders and farmers are not always located in close proximity to one another. And, while initial results may look promising, participatory plant breeding does not yet have a proven long-term record that can be evaluated.

It should be noted that early generation material from crosses will nearly always be less productive than either the best of the starting (parent) material or the final selections from the breeding process, since they contain undesirable gene combinations. Thus, release of early generation (segregating) material could lower farmers' yields in the short term. The need to maintain such populations separate from the farmers' main crop imposes additional burdens of management on the farmer. Some farmers may not have the capacity or experience to carry out selection from highly segregating materials. For these and perhaps other reasons, in all the case studies analysed so far, selections from early segregating materials have involved substantial breeder input and supervision: farmer-managed selections are carried out only on research stations, while on-farm trials are largely breeder managed.

An advantage of participatory approaches is that improved material can be made available much earlier than with conventional approaches. The corollary of this, however, is that material is not thoroughly tested before being released to farmers, and this may entail some risk.

There is often wide variety between farmers within a single community in terms of capacity, willingness and aptitude to experiment; goals (maximizing production; versus ensuring stable minimum production; production for sale versus for subsistence; for staples versus special culinary characteristics; etc.).

Preferences will vary according to wealth, social status; gender; age and experience. In many communities some farmers play a leading role in germplasm management. Depending upon the social structures, ensuring participation of these farmers in breeding programmes will not necessarily guarantee that all farmers in the community benefit, or even that the needs of other farmers will be identified. Often the poorest members of society may be the least likely to form groups or otherwise ensure their own representation. Therefore the poorest and most vulnerable groups can still be marginalized by “participatory” approaches.

There is little experience of formal-sector breeders and farmers working closely together in plant breeding programmes. Institutional modalities and incentive structures have not been worked out, and there may be policy and regulatory obstacles. The economics of participatory plant breeding programmes is unknown. Little can be extrapolated from the research-oriented programmes which have been carried out to date. However, it is clear that there are gaps in terms of farmers and environments which the commercial sector and centralized public programmes cannot address without a certain degree of devolution to farming communities themselves. Breeding for specific adaptation to a range of different environments requires a decentralized approach, which may only be feasible if farmers are involved.

If participatory plant breeding is successful in delivering new varieties to farmers it may lead to the displacement of traditional landrace varieties, thereby contributing to genetic erosion. Nevertheless, other things being equal, decentralized and participatory approaches to plant breeding are likely to increase genetic diversity on-farm, in comparison with conventional approaches to breeding for two reasons:

a) different farming communities, working in different environments, will tend to adopt different “solutions”, therefore farm to farm diversity will be higher;

b) if farmers have access to, and are able to experiment with, more material, they are able to maintain more diversity within farms.

Were participatory approaches to be widely employed, a number of constraints in the institutional systems would need to be overcome, including:

- **Incentives and rewards to plant breeders:** Generally, plant breeders are recognized for the varieties they produce and the extent to which these are adopted. New incentive mechanisms may be needed to encourage earlier release of breeding populations, where safe and appropriate.

- **Incentives to use local landraces and/or involve local communities.** Support to national agricultural research systems may be needed to stimulate the use of local landraces, to strengthen the role of farmers in realizing more demand-driven breeding programmes and to cover risks involved in their participation.
- **Variety release systems:** Most landraces and material bred specifically for adaptation to marginal conditions would fail the requirements of variety release systems which demand uniformity and stability. Adjustments to the existing regulatory frameworks, or new *sui generis* systems, may be needed. Regulations requiring or encouraging farmer-evaluation as a precondition for release, allowing multi-authored releases, would provide additional incentives.
- **Seed production and distribution:** National seed systems often supply only a small proportion of a country's total seed needs and these relate mostly to requirements in more favourable environments. In this case, it might be appropriate for the national system to work with effective local seed systems in order to supply a greater range of material for a wider range of environments.
- **Collection and documentation of germplasm and its movement:** The usefulness of *ex situ* collections for farmer/community breeding is limited by lack of information on what they contain. Evaluation of germplasm accessions, drawing upon farmers' knowledge, will encourage greater use of the material by farmers and others.

Considerable experience in participatory development processes has been gained in many fields including rural development,[50] community health systems and even in industrial product development involving consumers.[51] Less work has been done in the field of participatory breeding, suggesting a need for research in a number of areas, not the least of which is the diversity in farmer/community systems. Training in participatory breeding is also needed for institutional breeders and local partners - farmers, NGOs, seed producers and perhaps even processors. They need to have some understanding of what the institutional system can do for them and how such support can be obtained.

■

## Annex 1-3 endnotes

1 Mazur BJ and Tingey SV (1995) Genetic mapping and introgression of genes of agronomic importance. *Current Opinion in Biotechnology,* 6:175-182.

2 Lande R (1991) marker-assisted selection in relation to traditional methods of plant breeding. In Stalker HT and Murphy JP *Plant breeding in the 1990s*, p. 437-451. CAB International, London.

3 Robertson DS (1989) Understanding the relationship between qualitative and quantitative genetics. In Helentjaris T and Burr B (eds.) *Development and application of molecular markers to problems in plant genetics,* p. 81-87. Cold Spring Harbor Press, Cold Spring Harbor, New York.

4 Jansen RC and Stam (1994) High resolution of quantitative traits into multiple loci via interval mapping. *Genetics*, 136:1447-1455.

5 Churchill GA and Doerge RW (1994) Empirical threshold values for quantitative trait mapping. *Genetics*, 138:963-971.

6 This table was taken from the following USDA homepage on Internet:gopher: //gopher.nalusda.gov:70/11/infocntr/pltgen/p_gen_map_prj.

7 References can be found in: Mazur BJ and Tingey SV (1995) op. cit., endnote 1.

8 Klein-Lankhorst R, Rietveld P, Machiels B, Verkerk R, Weide R, Gebhardt C, Koornneef M and Zabel P (1991) RFLP markers linked to the root knot nematode resistance gene Mi in tomato. *Theoretical and Applied Genetics*,. 81:661-667.

9 Baum M, Laguda ES and Appels R (1992) Wide crosses in cereals. *Annual Review of Plant Physiology and Molecular Biology,* 43:117-143.

10 Thomas BR and Pratt D (1981) Efficient hybridization between *Lycopersicon esculantum* and *L. peruvianum* via embryo callus. *Theoretical and Applied Genetics*, 59:215-219.

11 McCoy TJ (1985) Interspecific hybridization of *Medicago sativa* L. and *M. rupestris* M.B. using ovule-embryo culture. *Canadian Journal of Genetics and Cytology*, 27:238-245.

12 Pelletier G (1990) Cybrids in oilseed *Brassica* crops through protoplast fusion. In Biotechnology in Agriculture and Forestry 10, Legumes and Oil Crops i, 418-433 (Ed. YPS Bajaj). Berlin, Heidelberg, New York: Springer Verlag.

13 Stalker HT (1980) Utilization of wild species for crop improvement. *Advances in Agronomy,* 33:111-147.

14 Sharma HC and Gill BS (1983) Current status of wide hybridization in wheat. *Euphytica,* 32:17-31.

15 *Agropyron* spp., *Psathyrostachys* spp., *Hordeum* spp., *Pseudoroegneria* spp., *Elymus* spp., *Leymus* spp., *Thinopyron* spp. and *Elytrigia* spp.

16 Jiang J, Friebe B and Gill BS (1994) Recent advances in alien gene transfer in wheat. *Euphytica*, 73:199-212.

17 Sharma HC (1995) How wide can a wide cross be? *Euphytica*, 82:43-64.

18 Duvick D (1989) The romance of plant breeding. Stadler Genetics Symposia, 19:39-54.

19 Walden R and Wingender R (1995) Gene-transfer and plant regeneration techniques. *Trends in Biotechnology*, 13:324-331.

20 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.

21 Schmidt K (1995) Whatever happened to the gene revolution? *New Scientist*, January 7:21-25.

22 Svab Z and Maliga P (1993) High frequency plastid transformation in tobacco by selection for a chimeric aadA gene. *Proceedings of the National Academy of Science USA*, 90:913-917.

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

24 Jørgensen R (1991) Silencing of plant genes by homologous transgenes. *AgBiotech News and Information,* 4:265-273.

25 Michelmore RW, Kesseli RV, Francis DM, Paran I, Fortin MG and Yang C-H (1992) Strategies for cloning plant disease resistance genes. In Gurr S, McPherson MJ and Bowles DJ (eds.) *Molecular plant pathology - a practical approach*, vol. 2, p. 99-124. IRL Press, Oxford, UK.

26 Flavell RB (1995) Plant biotechnology R&D - the next ten years. *Trends in Biotechnology*, 13:313-319.

27 Dangl JD (1995) Piece de resistance: novel classes of plant disease resistance genes. *Cell*, 80:363-366.

28 Michelmore RW (1995) Isolation of disease resistance genes from crop plants. *Current Opinion in Biotechnology,* 6:145-152.

29 Ibid.

30 Dixon MS, Jones DA, Keddie JS, Thomas CM, Harrison K, Jones JD (1996) The tomato Cf-2 disease resistance locus comprises two functional genes encoding leucine-rich repeat proteins. Cell 84:451-459.

31 Delanany X, Lavallee BJ, Proksch RK, Fuchs RL, Sims SR, Greenplate JT, Marrone PG, Dodson RB, Augustine JJ, Layton JG, and Fischoff DA (1989) Field performance of transgenic tomato plants expressing the *Bacillus thuringiensis* var. *kurstaki* insect control protein. *Bio/Technology,* 7:1265-1269.

32 Knauf VC (1995) Transgenic approaches for obtaining new products from plants. *Current Opionion in Biotechnology*, 6:165-170.

33 Mariani C, De Beuckeleer M, Truettner J, Leemans J and Goldberg RB (1990) Induction of male sterility in plants by a chimaeric ribonuclease gene. *Nature*, 347:737-741.

34 Mariani C, Gossele V, De Beuckeleer M, De Block M, Goldberg RB, De Greef W and Leemans J (1992) A chimaeric ribonuclease-inhibitor gene restores fertility to male sterile plants. *Nature*, 357:384-387.

35 Several oils are currently only available from crops that for geoclimatic reasons are not grown in Europe and North America, where the key markets are. Rather than domesticate new temperate crops, such as *Cuphea* and *Umbelliferae* spp., or adapt tropical or subtropical crops, such as oil-palm and castor bean, to temperate climates, current research focuses on genetic engineering to introduce genes for the

> production of these oils into temperate region oilseed crops. For example, there have been initial attempts to engineer energetically oilseed rape to produce oil currently only available from jojoba (*Simmondsia chinensis*) (US Patent No. 5370996).

[36] Hemming D (1994) Conference Reports: Fourth International Congress of Plant Molecular Biology. *AgBiotech News and Information,* 6:217-230.

[37] Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biological Review*, 68:539-562.

[38] Hallauer A (1992) Recurrent selection in maize. *Plant Breeding Reviews*, 9:115-179.

[39] Op. cit., endnote 37.

[40] Fowler C (1994) Unnatural selection: technology politics and plant evolution. Gordon and Breach Science Publication, Yverdon, Switzerland.

[41] Jefferson RA (1994) Apomixis: A social revolution for agriculture? *Biotechnology and Development Monitor*, 19:14-16.

[42] A joint project between the Institut français de recherche scientifique pour le développment en coopération (ORSTOM) and the International Centre for Maize and Wheat Improvement (CIMMYT) for the introgression of apomixis from *Tripsacum* into maize is reportedly nearing completion, while a USDA project is making substantial progress in introgressing apomixis from *Pennisetum squamulatum* into pearl millet.

[43] The International Centre for Tropical (CIAT) is mapping a single gene locus associated with apomixis in the tropical forage, *Bracharia*. CAMBIA, in Australia, is establishing an international molecular apomixis project to coordinate and conduct genetic engineering for the development of apomictic food crops.

[44] Based on the work of the Wageningen Workshop on Participatory Breeding, organized jointly by IDRC, FAO, IPGRI and the Dutch Genebank (CGN/CPRO-DLO) which brought together a group of 24 technical and social scientists actively involved in farmer participatory breeding for less favourable environments from various CGIAR institutes, some national institutions and donor organizations.

[45] This section is based on the study Berg T, Bjørnstad A, Fowler C and Skroppa T (1991) *Technology options and the gene struggle*. NORAGRIC, Agricultural University of Norway, Aas, Norway.

[46] Fowler C op. cit., endnote 40, p. 14 ff.

[47] Eyzaguirre P and Iwanaga M (eds.) (1996) *Participatory plant breeding*. Proceedings of a Workshop on Participatory Plant Breeding, 26-29 July, Wageningen, the Netherlands. IPGRI, Rome.

[48] Ibid.

[49] Quisumbing AR, Brown LR, Feldstein HS, Haddad L and Pena C (1995) *Women: the key to food security*. IFPRI, Washington, DC.

[50] Chambers R, Pacey A and Thrupp LA (1993) *Farmer first: farmer innovation in agricultural research*. Intermediate Technology Publications, London.

[51] Nelson N and Wright S (1995) *Power and participatory development: theory and practice*, Intermediate Technology Publications, London, 207 pp.

# ANNEX 1-4
# Legal and Economic Methods Relevant to PGRFA

## A1-4.1 METHODS FOR VALUATING PGRFA

A number of methods have been developed by economists for assessing the value of public goods which have in turn been applied to the valuation of biological diversity. Many attempts have been made to estimate the value of various ecosystem functions (or "services"), rather than genetic resources *per se*, and consequently have little application to the valuation of genetic resources for food and agriculture.

Most methods evaluate biological diversity as non-marketed goods and services, by estimating people's "willingness to pay" if they were for sale. There are several approaches:[1]

- **Direct methods** use simulated markets to get users to state their "willingness to pay". These are the only methods currently available for assessing "non-use" value (e.g. the aesthetic value of a forest). In the "contingent valuation method", respondents are asked hypothetical questions about their monetary valuation of a situation: i.e. "how much would you be willing to contribute for the conservation of X?".
- **Indirect methods** use simulated markets to reveal the preferences of resource users. These include the widely used "travel cost method" which determines how far people (e.g. rural food producers, tourists) would be willing to travel to visit a protected area, for example.
- **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. These methods could be used to estimate the value of PGRFA in breeding programmes, for example, by assessing the value of the inputs based on their contribution to the costed product, the finished variety.

There have been few studies which attempt to assign a value to plant genetic resources for food and agriculture, *per se*. Direct methods, using simulated markets, have not been applied to PGRFA.[2] Indeed, the following examples suggest that indirect methods are more applicable:[3]

- **Surrogate market methods.** PGRFA have value as an insurance policy (see Chapter One, section 1.4); maintaining a wide range of diverse varieties reduces threats to food security. Quantitative estimates of this value may be inferred from crop insurance markets, which provide an alternative means of reducing risk. The widespread adoption of a limited range of modern varieties, and consequent increased yield fluctuations, have led to growing demand for crop insurance in some countries (See Chapter One, section 1.5.1).
- **Production function methods.** Yield gains in agriculture result from genetic and other inputs (including agrochemicals and capital machinery) for which costs are often known. The contribution of genetic resources (in the form of improved varieties) to productivity gains can be estimated, using production-functions. However, such estimates of the value of genetic inputs include both the value of genetic material *per se* (genes and gene complexes) and the capital, labour and technology costs involved in plant breeding.[4] A further step would be to analyse the difference between the benefits accruing from the improved variety, and the costs of the other factors. This could be done for crops, using, for example, data such as held by CIMMYT on all wheat varieties released by National Agriculture Research Systems in the developing world between 1966 and 1990.

### Assessments of the local value of PGRFA

The range of ways that plant genetic resources matter to local people should be recognized 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 ephemeral 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 need to be based on local knowledge, uses and values of wild resources and, therefore, must involve local people - men *and* women - in the valuation process.[5] Local level valuation methodologies are being developed by some institutes, such as the International Institute for Environment and Development (IIED), to attempt to address some of these problems.[6]

## A1-4.2 POSSIBLE MECHANISMS FOR REALIZING THE VALUE OF GENETIC RESOURCES AND OF RELATED INNOVATIONS[7]

A range of legal instruments and other mechanisms are relevant as possible mechanisms for the sharing of benefits derived from the use of plant genetic resources. These fall into three categories:

- intellectual property rights (and other rights over intangible property);
- contracts (including material transfer arrangements);
- international agreements on access to, use of and remuneration for PGRFA.

Each of these 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 explored further.

### A1-4.2.1 Intellectual property rights

Intellectual property rights (IPRs) relate to an intangible content of processes or goods. In the case of living forms, for instance, they may relate to the information contained in genes, or other sub-cellular components, in cells, propagating materials or plants. Intellectual property rights are not equivalent to property rights over the physical objects containing such information, but are rights to exclude third parties from producing or selling the objects in question, without prior agreement. The “exclusive” rights of the title-holder are exercised indirectly over the materials containing the protected information, and in this way the production, storage, circulation and trade of such materials is affected. Generally, exclusive rights are exercised through the payment of royalties to the IPR title-holder for use or sale of the protected product.

Intellectual property rights reward, and it is argued promote, innovative activities[8] as well as acts of discovery, in some cases. They provide, through a monopoly right for a limited period, a return on investments in human capital, even when the protected subject matter is a natural substance. (Patents on genes, for example, would compensate for the human effort involved in isolating, sequencing and otherwise identifying the genes and their functions.)

The main areas of intellectual property relevant to plant genetic resources for food and agriculture are patents and plant breeders’ rights (a *sui generis* system - that is a system that applies specifically to plant varieties). Trade secret protection is also relevant, particularly in connection with hybrid seeds.

## Types of intellectual property rights

### Patents

The Paris Convention for the Protection of Industrial Property is the main relevant international convention in this field, but it has no specific rules on patentability, patent systems being essentially national rather than international systems. However, the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPs), adopted as a part of the outcome of the GATT Uruguay Round, introduces new international rules that are of relevance.[9]

There are still considerable differences among national laws regarding the patentability of inventions relating to plants. There is however a trend - at least in industrialized countries - towards accepting the patentability of genes, cells and microbiological processes, including, in certain cases, naturally occurring materials.[10] No major differences exist in industrialized countries with respect to the patentability of micro-organisms and of microbiological processes.[11]

Micro-organisms are generally deemed to include cells as well as subcellular components. Under this principle, and the approach referred to in the previous subsection, the patenting of cells, subcellular components and genes, whether pre-existing or modified, has become possible.

In the United States, for example, genes that are engineered by mutagenesis or genetic engineering techniques, as well as those not previously known to exist in nature, are patentable.[12] Claims in these cases normally refer to an isolated DNA sequence, DNA constructs and newly transformed plants derived from them, although claims often include natural DNA sequences without limitations. Box A1.10 includes a list of some patents issued in the United States.

There are substantial differences between countries with respect to the patentability of plant varieties. Patenting of plant varieties is not permitted in most countries, including European countries, but is permitted in the United States (Box A1.10).

### Plant breeders' rights

Plant breeders' rights (PBR), sometimes known as plant variety protection (PVP), are a *sui generis* form of intellectual property right protection, designed specifically for the propagating materials of plant varieties.[13]

**Box A1.10 Examples of patents issued in the United States**

- Sunflower (*Helianthus annus* L.) regeneration
- Potato (*Solanum tuberosum* L.) cultivar
- Inbred maize line
- Hybrid maize line
- Tryptophan overproducer mutants
- Mushroom (*Agaricus bisporus* L.) mutant strains
- Process producing odourless soybean
- Bean (*Phaseolus vulgaris* L.) plant having low pod-detachment force
- Squash (*Cucurbita pepo* L.) cultivar
- Tetraploid maize and method to produce
- Process for microplant propagation
- Herbicide resistance in tobacco (*Nicotiana tabacum* L.)
- Kiwi (*Actinidia chinensis* Planch) fruit plant

*Source*: Jondle (1989), p. 8

Most PBR legislation is in accordance with the UPOV Convention, which establishes minimum standards. As of January 1996, UPOV had 30 member countries, most of which are members of the 1978 Convention. The Convention was revised in 1991, but since no country has yet ratified the 1991 Convention, it has not yet entered into force. Members are mostly developed countries, but include Argentina, Chile, South Africa and Uruguay. Some other countries have their own system of plant breeders' rights, outside of the UPOV framework, including a regional system in the Andean Pact countries.

Plant breeders' rights characteristically recognize two exceptions to the exclusive rights of the breeder. The so-called "farmers' privilege" allows farmers to reuse, and sometimes resell as seed, limited quantities of seeds obtained from the cultivation of protected varieties. The "breeders' exemption" allows the use of a protected variety under certain conditions as the basis for further varietal development by third parties. These exemptions are often considered to constitute the main difference between the system of plant breeders' rights and the patent system.[14] In the 1991 revision of the Convention, however, the farmers' privilege was changed from a general rule to an exception.[15]

The concept of "essentially derived varieties" was introduced in the 1991 revision of the UPOV Convention, in order to prevent the protection of varieties that only reflect "cosmetic" changes with respect to pre-existing protected varieties.[16] However, there is currently much debate over how the "essentially derived varieties" clause might be implemented; some prefer it to be based on genetic distance (measured using molecular markers), while others favour using agronomic (i.e. phenotypic) characters.

The revised Convention also prescribes that any member country may extend the breeders' rights to the end products, when the breeder has had no reasonable opportunity to exercise his/her right in relation to the harvested material.

#### Other forms of protection and remuneration of possible relevance to PGRFA

**(a) Trade secrets.** Valuable knowledge may be preserved by being kept secret, particularly in the case of the application of plants for therapeutical purposes. Holders of such knowledge may well be protected under the concept of unfair competition rules, which do not require previous registration or other formalities. Trade secrets protection, unlike patents, does not confer an exclusive right, but does grant the right to prevent the acquisition and use by third parties of protected information in a manner contrary to honest commercial practices. Secret information of commercial value may be protected under laws relating to trade secrets.

**(b) Appellations of origin.** This title regulates the use of a geographical identifier relating to a specific place, region or country, when the typical features, or special characteristics of a product are closely related to a particular geographical area or region, such as appellations of origin for wines and spirits. This mode of protection might, in a limited number of cases, be applied to certain crop varieties or products, signifying their origin and uniqueness. The protection conferred under such titles may be exercised through associations representing the producers of the region or area concerned. It should be noted, however, that an appellation of origin does not protect a specific technology or knowledge as such, but only prevents the false use of the geographical identifier.[17]

**(c) Protection of expressions of folklore.** The UNESCO/WIPO Model Provisions for National Laws for the Protection of Expressions of Folklore against Illicit Exploitation and other Prejudicial Actions have been mentioned as a possible framework for the protection of traditional knowledge. The model provisions attribute rights not only to individuals, but also to communities, and allow the protection of ongoing or evolutionary creations.[18] This type of protection belongs in the area of copyright, where only the expression of a work, and not the underlying ideas, is protectable.[19] This limits its usefulness as a means of protecting and compensating methods or knowledge of a functional character.

**(d) Cultural property.** The Convention on the Means of Prohibiting the Illicit Import, Export and Transfer of Ownership of Cultural Property, administered by UNESCO, has been suggested as a possible mechanism for the protection of traditional knowledge.[20] Parties to the Convention may designate the categories of property to be considered "cultural property"; these may include "rare collections and specimens of fauna (and) flora". The property to be protected may have been created by individuals or collectively.

**(e) Remuneration rights.** Another form of protection might be provided by a system in which a right to remuneration, not associated with the exercise of an exclusive right, is ensured in order to compensate the contributions made by communities. Some situations involving intellectual property have been addressed by systems of this type. In some other areas of copyright and similar rights, difficulties in exercising exclusive rights have led to the establishment of remuneration schemes, with collective administration organizations. These organizations collect licence fees and other forms of remuneration and distribute them among the authors concerned. Examples of remuneration rights include:

- **the public lending right**, that is, the right of authors to a remuneration (directly paid by the state in certain countries), for the lending of their books by public libraries. The remuneration is distributed among authors according to certain criteria, such as the number of books in the libraries' stocks;
- **the royalty on blank audio and video tapes** that has been established in many countries, specifically for tapes suited for private use. This royalty is intended to compensate the title-holders of works published on audio and video tapes for the copying of these works without their consent, and is premised on the practical impossibility of actually controlling private copying.

### Application of intellectual property rights to PGRFA

A great deal of attention is currently being focused on the development of IPR or IPR-like systems for the protection of plant varieties, germplasm and related indigenous knowledge. Two recent developments account for this:

The TRIPs agreement obliges developing countries to provide for IPRs on plant varieties. At the same time, the entry into force of the Convention on Biological Diversity is seen to provide an opportunity to put in place systems of protection for plant genetic resources and associated knowledge originating in developing countries. These two developments are addressed below.

### The TRIPs Agreement

The TRIPs Agreement, adopted as part of the outcome of the Uruguay Round of GATT, has introduced new international rules that are relevant to the application of IPRs to PGRFA. Under article 27.3.(b) of the Agreement, members may exclude from patentability:

> "plants and animals other than microorganisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes. However, Members shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof. The provisions of this sub-paragraph will be reviewed four years after the entry into force of the WTO Agreement."

As stipulated in the article, members must provide protection for "plant varieties", either by patents or by "an effective *sui generis* system or by a combination of both". The reference to a *sui generis* system suggests the Plant Breeder's Rights regime, but the possibility is open to developing new *sui generis* forms of protection to meet specific needs and concerns.

### The possible extension of intellectual property rights over landraces and other heterogeneous agro-biodiversity

As noted above, the rationale for IPRs is to reward innovation. In the field of PGRFA, IPRs are used mostly to reward the efforts of breeders or biotechnologists in developing new varieties. A *sui generis* regime for the protection of landraces might, using the same logic, reward the effort by farmers and communities, in selecting and improving plant genetic resources.

It has been suggested that a specific type of rights might be introduced for genetic material itself (effectively, the information content of genetic material). Such rights would reward and promote investment in *in situ* management and improvement. These rights might be vested in states or in private parties, including farmers and communities.[21] The precise nature, scope, enforceability and effects of such rights would require further examination.

There are, however, a number of associated difficulties inherent in both of these approaches. Some of these difficulties concern the nature of the material to be protected.

The current application of intellectual property rights to PGRFA is limited to the protection of modern commercial crop varieties (essentially through plant breeders' rights) and other products of biotechnology (generally under patents). These regimes, discussed above, require the protected material to be recognizable and, in cases of rights infringement, to be easily traceable. The accent has therefore been on distinctness, based on uniformity and on the stability of the protected material over generations. However, the value of landraces lies precisely in their variability (lack of homogeneity) and their continuing evolution (lack of stability over generations), which makes definition, recognition and tracing difficult. For specific genetic traits, it may be easy to define the subject, but more difficult to identify the area of origin: such traits may occur *in situ* in more than one country, and be found in *ex situ* collections in or outside the country.

In the specific cases where these problems can be resolved, various legal issues remain to be considered. These include:

- the level and nature of human intervention, as well as the *innovation required*, if any, for a given material to be protectable;
- identification of the appropriate *title-holder* (the genetic information contained in landraces is generally the result of the interaction of many landraces over time and geography);
- the *attribution of rights* to particular farmers, communities, regions and countries;
- the *duration* of protection for an intrinsically evolving material, for which the date of "innovation" cannot be established.

Another key issue is whether such intellectual property rights would actually operate in favour of their intended *beneficiaries*. The acquisition and, particularly, the *enforcement* of rights may only be possible for those with financial resources and adequate technical and legal support.[22] The availability of rights is useless if they cannot actually be enforced. Enforcement depends on proving *infringement*,[23] on the existence of preventive measures and remedies against infringement and, above all, on the capacity to monitor possible infringement of the rights and to bear the costs of administrative and judicial procedures.

In cases where new legal regimes of this nature can be developed, they are perhaps more likely to be applied when the object is to identify a chemical substance of potentially high commercial value, particularly a medicinal substance. The applicability of this approach to plant genetic resources for food and agriculture is subject to two main constraints. First, unlike medicinal or other chemical substances, the value of plant varieties is usually dependent upon a large number of genes, frequently originating from many different sources. It would be very difficult to isolate or determine the value attributable to specific genes found in a specific region, let alone country or locality.[24] Second, in most cases the same genes might well be found in other areas, including in existing *ex situ* collections.

### A1-4.2.2 Contracts

The use of contracts to govern transactions involving the use of genetic diversity and other biological resources is increasing, particularly in the field of "bio-prospecting".

Contracts are often used in bilateral arrangements. They might include the payment of a fee for access to the resources, and/or an agreement to provide a share of profits if commercial benefits are realized. To date, however, all such arrangements relate to the exploitation of biological resources for pharmaceutical or industrial purposes, primarily through the extraction of chemical substances. As far as is known, such arrangements have not been used to regulate access to genes for plant breeding.

Contracts could also be used in the context of a multilateral agreement. It has been proposed that international franchise agreements could be used for maintaining diverse genetic resources which are international public goods.[25] Such contracts could take the form, for instance, of a tripartite agreement (between a state, the international community and the franchisee, through a special fund) under which the compensation would be established and paid in exchange for the actual conservation of germplasm.

#### Material transfer agreements (MTAs)

Material transfer agreements are increasingly used by industry and public sector laboratories in some countries, as well as in international germplasm exchanges. They permit access to certain samples of germplasm, generally under the condition that they will be used for research purposes only, without transferring title over their intangible content. MTAs are contractual arrangements concluded between two or more parties. As such they are legally sanctioned in most countries, and are generally regarded as subject to trade secret law.[26]

MTAs may oblige the germplasm recipient not to seek patents over the material or over its derivatives or, in cases where it is stipulated that such rights can be obtained, to share them or the royalties deriving from their exploitation with the provider. In general, the recipient undertakes to negotiate with the provider the distribution of any profits that may result; in other words, negotiation is left until after it has been demonstrated that there will be profits.[27]

The use of MTAs is suggested in the International Code of Conduct for Germplasm Collecting and Transfer, in order to promote sharing of the benefits derived by users of collected material with the countries and communities from which it was collected.[28] MTAs could be useful in both bilateral and multilateral arrangements.

Simple systems have been developed by the International Agricultural Research Centres (IARCs) for the transfer of "designated germplasm" from *ex situ* collections maintained in international centres which are part of the International Network of Ex *Situ* Collections (Box A1.11). Such agreements are being used for material collected prior to the entry into force of the Convention on Biological Diversity and for material for which countries have given permission for it to be made available on the stated terms.

MTAs have been proposed to facilitate sharing of benefits in line with the Convention (Box A1.12).

Recently, the FAO Commission on Plant Genetic Resources requested that IPGRI undertake a study of possible approaches to facilitating access to plant genetic resources and promoting the equitable sharing of the benefits arising from their use, in the context of on-going negotiations for the revision of the International Undertaking and discussions in the Conference of the Parties to the Convention on Biological Diversity.

**Box A1.11 Extract from "standard order form" of germplasm from collections of the IARCs[29]**

"I/we agree:

- not to claim ownership over the material received, nor to seek intellectual property rights over the germplasm or related information;
- to ensure that all successive persons or institutions to whom I/we make samples of the germplasm available are bound by the same provision"

### Box A1.12 Possible model provisions for MTAs in line with the Convention on Biological Diversity

The recipient of germplasm from a centre would be required:

- to acknowledge the source nation's contribution in publications and variety descriptions;
- to notify the centre of any transfer of the material or its derivatives to a third party, and to require a similar restriction when transferring the material to that third party;
- to file reports on pre-breeding/evaluation results;
- in the event of successful commercialization of research results deriving from the material, to provide a reasonable share of net profits to the source nation in an amount and a form to be agreed upon between the recipient and that nation;
- to observe the following restrictions concerning intellectual property:

(a) not to seek rights on the material itself;

(b) not to assert rights on derivatives in the territory of the source country and other developing countries, unless the recipient has actually marketed a product containing the technology in the country concerned, within five years after issuance of such rights, or the derived material traces less than one-quarter of its lineage to the material obtained from the centre.

The recipient's obligations lapse after [30] years.

*Source*: Adapted from Barton and Siebeck (1994)

## A1-4.3 INTERNATIONAL FUNDING MECHANISMS

One way of compensating and providing incentives to farmers, their communities and countries for their continuous work on the development and conservation of PGRFA is through an international fund. Through such a fund, the international community might ensure a flow of funds to a particular agro-ecological region, or specific countries or areas, in return for the services of conserving the diverse resources contained there.

The World Heritage Fund of the UNESCO-sponsored World Heritage Convention provides a useful model. 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. Another programme, which is more applicable to the conservation of plant genetic resources for food and agriculture *in situ*, is the system of biosphere reserves under UNESCO's Man and the Biosphere Programme.

A system of *agro-biodiversity reserves*, to protect plant genetic resources of interest to food and agriculture, has also been suggested. Such reserves might include:

- traditional farming areas, to maintain traditional production systems and land-uses;[30]
- areas rich in the wild relatives of crops.

The international community would make regular payments based on development opportunities foregone, and costs involved. In effect, local communities and countries would be compensated when the locally optimal development plan was deviated from, in order to conserve genetic diversity. Such an approach might be especially justified when genetic resources of particularly high importance are involved.[31] In certain cases, it could also be combined with existing biosphere reserves.

The FAO International Undertaking on Plant Genetic Resources,[32] as interpreted through its annexes which provide[33] for an international fund to implement Farmers' Rights, offers a means to share benefits with or compensate countries and their farming communities, for developing and making available plant genetic resources on a continuing basis. The operating mechanisms of this fund have not yet been established, but it has been agreed that the policies, programmes and priorities of the fund, and other funding mechanisms, will be determined and overseen by countries through the Commission on Genetic Resources for Food and Agriculture. A number of issues, however, remain to be considered and clarified with regard to the implementation of such rights:

- **Rationale for funding.** This could be based on compensation for past contributions or incentives for future contributions, though the distinction may be more academic than real.
- **Funds needed.** Determination of the amount of funding needed for compensation depends on the methodologies used to measure the value of farmers' contributions. As discussed in section A1-4.1, it is difficult, if not impossible, with present techniques, to arrive at a value objectively. One methodology could be the calculation of the incentives that would need to be provided in order to conserve effectively and continue to develop a given level of diversity of PGRFA on a global level.[34]
- **Entitlement to benefits.** Farmers and their communities may be the principal final beneficiaries, but institutional mechanisms may need to be established to represent their interests. This could be achieved, for instance, through governments, collective associations of farmers or other entities.
- **Funding obligations.** Governments might contribute to a fund on a mandatory basis in order to achieve the effective implementation of Farmers' Rights within a reasonable period.[35] The level of contributions to be made by individual countries could be determined in accordance with various criteria, such as the sales of improved varieties, the size of the seed trade, the value of crop production, value added in agriculture, gross domestic agricultural product or simply gross domestic product. A fair distribution of charges might also be derived from the scale of country contributions to FAO or UN.
- **Use of funds by the beneficiaries.** Two possibilities may be envisaged: (i) the beneficiaries would not be required to apply the amounts received to any particular activity - it would be assumed that the expectation of future compensation would be a sufficient incentive to ensure the continuation of conservation/maintenance activities by beneficiaries;[36] and (ii) payments would be linked to actual commitments or even to specific activities related to the conservation and development of diverse PGRFA. This could be achieved by financing programmes evaluated, approved and monitored by the fund.[37]
- **Allocation of the funds.** Criteria for fund allocation would need to be defined. These might take into account, for instance, the "value" of the PGRFA in question, risks of extinction, national income levels and the ability to conserve.[38] Funds might also be allocated for specific activities, as above.

■

## Annex 1-4 endnotes

1 Barbier EB, Brown G, Perrings C, Dalmazzone S, *et al.* 1995, Chapter 12 in the Global Biodiversity Assessment.

2 As Evenson points out, contingent valuation approaches are ill-suited to measuring the value of genetic resources. An average individual knows little about international germplasm collections for example, and has little basis for gauging their value. The responses elicited from surveys may thus be inconsistent or even meaningless: Evenson RE (1993) *Genetic resources: assessing economic value*. Yale University, Department of Economics, New Haven, Connecticut, USA.

3 FAO (1994) *Revision of the International Undertaking. Analysis of some technical, economic and legal aspects for consideration in Stage II*. CPGR-Ex 1/94/5 Supp.

4 National Research Council (1993) *Agricultural crop issues and policies,* Chapter 13. Committee on Managing Global Genetic Resources: Agricultural Imperatives, Board on Agriculture, NRC, Washington, DC.

5 Barbier EB, Brown G, Perrings C, Dalmazzone S, *et al.* (1995) The economic value of biodiversity. In *Global biodiversity assessment*, Chapter 12. UNEP, Cambridge University Press, Cambridge, UK.

6 Hinchcliffe F and Melnyk M (1995) *The hidden harvest: the value of wild resources in agricultural systems*. IIED, London.

7 This section is based on FAO (1994) 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., FAO, Rome, where a more complete treatment can be found.

8 Correa ibid.

9 Mention should also be made of the Budapest Treaty on the International Recognition of the Deposit of Micro-organisms for the Purposes of Patent Procedures which establishes a system aimed at facilitating the deposit of micro-organisms as a means of complying with the disclosure requirements of patent laws, and to the Patent Cooperation Treaty (Washington, DC, 1970), which simplifies the obtaining of protection, when this is sought in several countries.

10 See for example, the Guidelines of Examination of the European Patent Office (Part C (IV), 2.1).

11 There are, however, some exceptions. In Norway the patent office has interpreted the plant and animal variety exclusion to preclude protection for micro-organisms, cell lines, viruses and plasmids. It is also uncertain whether RNA or DNA macromolecules are patentable (Bent SA (1987) *International property rights in biotechnology worldwide*, p. 514. Stockton Press, New York.)

12 Bent SA (1987) *Intellectual property rights in biotechnology worldwide*. Stockton Press, New York.

13 With the exception of the laws of the United States and the Republic of Korea, plant breeders' rights are generally applied to both sexually and asexually reproducing plants. The Republic of Korea recently amended its law to provide protection for all kinds of plants, effective 1 March 1998.

14 These are not, however, the only important differences. There are also significant differences with regard to the subject matter of and the requirements for protection.

[15] The 1991 revised UPOV Convention transforms the way in which the rights of farmers to reuse farm-saved seeds on their own land are expressed. These rights previously depended on a generally accepted interpretation of the term "production for purposes of commercial marketing", which excluded from the scope of the Convention the reuse of farm-saved seed of protected varieties, by farmers, on their own lands. The expression "production for purposes of commercial marketing" has now been widened to read "production or reproduction", but an optional clause allows individual Contracting Parties to restrict plant breeders' rights in order to permit farmers to use, for propagating purposes on their own holdings, the product of the harvest that they have obtained by planting the protected variety on their own holdings. Thus, in practical effect, the farmers' privilege is changed from a principle to an exception.

[16] This may also help to dissipate breeders' fears of the eventual impact of the patenting of genes that may be incoporated into breeders' varieties.

[17] In this sense, this form of protection is closer to the trademarks regime than to patents.

[18] Bolivia, Cameroon, Central African Republic, Côte d'Ivoire, Ghana, Guinea, Madagascar, Morocco, Rwanda and Senegal are reported to have implemented rules within the framework of the Model Provisions.

[19] In accordance with the so-called idea-expression dichotomy, protection is conferred to the form in which a work is expressed, and not to the concepts, ideas, methods, etc. that underlie its expression. By this principle, for instance, the reverse engineering of integrated circuits and computer programs has (under certain conditions) been allowed by national legislation.

[20] Reid, Walter VC (1993) *Biodiversity prospecting: using genetic resources for sustainable development*. World Resources Institute, Washington, DC.

[21] See Sedjo RA (1998) Property rights and the protection of plant genetic resources. In Kloppenburg J Jr (ed.) *Seeds and sovereignty: the use and control of plant genetic resources*. Duke University Press, North Carolina, USA. (Note, however, that this author refers to "newly discovered natural genetic resources", p. 308); and Swanson TM, Pearce DW and Cervigni R (1994) *The valuation and appropriation of the global benefits of plant genetic resources for agriculture*. (Centre for Social and Economic Research on the Global Environment, and University of Cambridge, UK. (unpublished)

[22] In fact, this is one of the major handicaps facing innovators in developing countries who wish to obtain patents abroad, because they are often unable to bear the costs of the acquisition, maintenance and defense of the rights.

[23] With respect to the effectiveness of available techniques, see Appendix 2.

[24] Biological prospecting contracts provide a framework for regulating the sharing of benefits in the case of the discovery of plants with new commercial applications. Benefits to donors of germplasm generally take the form of payments in advance 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 for medicinal or industrial purposes, but not to the collection of PGRFA. 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 Surinam.

[25] See Swanson TM, Pearce DW and Cervigni R op. cit., endnote 21.

[26] Barton J and Siebeck W (1994) *Material transfer agreements in genetic resources exchange. The case of the International Agricultural Research Centres*. Issues in Genetic Resources, No.1, IPGRI, Rome.

[27] Ibid.

[28] FAO International Code of Conduct for Germplasm Collecting and Transfer, Articles 13 and 14.

[29] FAO (1995) CPGR-6/95/12.Add1, June 1995.

[30] The European Union in the last reform of the Common Agricultural Policy, concluded in 1991, introduced an "accompanying measure" that gave its 12 member states the possibility of providing premiums to their farmers who continue to cultivate plant varieties, or raise animal breeds, that are threatened with extinction.

[31] It should be borne in mind that there is a complex interaction between farmers' socio-economic conditions and their willingness and ability to continue the selection and maintenance practices required to maintain landraces successfully. These potential limitations need to be considered.

[32] FAO Conference Resolution 8/83.

[33] FAO Conference Resolutions 4/89, 5/89 and 3/91.

[34] For such incentives to be successful, such incentives would need to be more than the opportunity cost of foregoing conversion to modern varieties; see Appendix 1.

[35] Annexes to the Undertaking refer to the need for substantial and sustainable funding, but do not directly address the issue of whether contributions must be mandatory.

[36] The intellectual property system, although theoretically grounded on ensuring the recovery and further financing of research and development costs, does not require the title-holder to apply the amounts received to research or any other particular end.

[37] The Global Plan of Action is probably relevant in this context.

[38] Such ability might be periodically verified on the basis of performance.

# ANNEX 2
# State of Diversity of Major and Minor Crops

## A2.1 INTRODUCTION

A number of crops identified as being of major importance for food security in one or more sub-regions (wheat, rice, maize, millet, sorghum, potato, sugar cane,[1] soybean, sweet potato, cassava, beans (*Phaseolus*), banana/plantain) are surveyed in this annex. Each of these crops supplies more than 5% of the plant-derived energy intake in one or more sub-regions[2] (see Chapter One, Figure 1.3). It should be noted that this is not a definitive list of staple or important food crops. Nonetheless, it does constitute a range of crops, which includes examples of different crop groups (cereals, food legumes, roots and tubers), species with different breeding systems (cross-pollinating, self-pollinating, clonally propagated) and crops of temperate and tropical origin. It also includes crops for which there has been very great investment in conservation and improvement, notably wheat, rice and maize, as well as crops for which there has been relatively little investment, such as cassava, sweet potato and plantain. A substantial share of energy intake is also provided by meat, which is ultimately derived from forage and rangeland plants. Forages and rangeland plants are therefore also surveyed.

For each crop, information is provided on the major regions of production/ consumption and the species in the gene pool; the state of diversity *in situ,* including any reports of genetic erosion and *in situ* conservation programmes; the size, nature and storage conditions of major *ex situ* collections; the extent of *ex situ* coverage of the gene pool and any identified collecting gaps; the extent of documentation, characterization and evaluation of collections; and utilization of accessions, breeding of improved varieties and changes in yield between 1961 and 1993. Further information on *ex situ* collections of a larger range of crops is provided in Appendix 2.

Information has been obtained from several sources, including FAO production statistics,[3] FAO Food Balance Sheets,[4] the recent genebank review of the International Agricultural Research Centres,[5] a CGIAR review of its mandate crops,[6] Country Reports[7] and the database of the FAO World Information and

Early Warning System (see Appendix 2). The acronyms for each genebank are listed in Appendix 2.[8] For some crops, information was obtained from scientific literature and crop experts.[9] Data on crop yields between 1961 and 1993 are derived from the FAO production yearbooks.[10]

The relative bias towards reporting on the collections in the CGIAR centres reflects the fact that more comprehensive information was available for these collections. There are few current estimates of the extent of gene pool coverage of global collections for these crops, therefore estimates from a 1987 report of genepool coverage are given.[11] In many cases there are high percentages of accessions for which the type of sample is not specified which makes it difficult to assess the actual relative proportion of wild relatives, landraces/old cultivars and advanced cultivars/breeding lines stored globally. The figures given for germplasm distribution refer to the total number of accessions distributed and not to the number of unique accessions distributed. The yield figures also provide information on sub-regions where yields are higher or lower than the global average. Where possible the higher- or lower-yielding regions are chosen to coincide with regions where production or human consumption is high. The y-axes of the crop yield graphs are adjusted so that comparisons of yield increases can be made between crops.[12]

A selection of minor crops and under-utilized species of importance for food and agriculture are surveyed in Table A2.1, at the end of this annex. Many of these were selected by recent regional meetings for Africa, Asia and Europe, organized by the International Centre for Under-utilized Crops (ICUC)[13] and IPGRI. The list constitutes a regional selection of minor and under-utilized crops which are important staples (bambara groundnut, fonio, yams, breadfruit, taro, chayote, *Amaranthus* spp, canihua, oca), under-utilized fruit crops (sapote, Spanish plum, tomatillo, durian, jackfruit), promising new industrial or oil crops (meadowfoam, safflower, lupins), vegetable crops (Lagos spinach, rice bean, jew's mallow), crops with potential for agricultural diversification through niche market development (rocket, buckwheat, walnuts) and various multipurpose trees. This list of under-utilized crops is only a small proportion of the variety of under-utilized crops globally and hence is only meant to be an indicative, rather than comprehensive selection. Many of these and other under-utilized crops have similar constraints to development such as lack of improvement or marketing programmes.

## A2.2 STATE OF DIVERSITY OF MAJOR CROPS

### A2.2.1 State of wheat genetic resources

**General**

Wheat is the world's most widely cultivated crop covering a harvested area of 219 million hectares. Total world production is 545 million tonnes (1995). The five largest producers are China (20%), India (12%), the United States (11%), France (6%) and the Russian Federation (5%). Wheat is important to food security in all sub-regions, especially in Central and West Asia and the South Mediterranean (Figure 1.3). As well as a number of cultivated *Triticum* species, there are many wild relatives in the wheat gene pool.

***In situ* status**

Genetic erosion is reported in the Country Reports of China, Uruguay, Chile and Turkey. Very few formal *in situ* programmes have been reported. Notable among these are the "dynamic gene preservation" strategy for wild emmer wheat in Israel and the recently initiated (1993) project to conserve wild wheat species in Turkey, with the support of the GEF.

***Ex situ* conservation**

Wheat is the crop with the largest number of accessions collected globally. Approximately 850,000 accessions are stored, mostly of Triticum. The largest holdings of wheat germplasm are held by CIMMYT for *Triticum* (13% of global total) and *Triticale* (38%) and VIR (Russia) for Aegilops (15%). Global base collections are maintained by CIMMYT (*T. aestivum* and *Triticale*) and ICARDA (*T. durum* and wheat wild relatives). Of the ten largest collections of Triticum, one is under long-term storage, six are under medium-term storage and the status of the other three is unreported (Appendix 2).

**Coverage/gaps**

It has been estimated that 95% of landraces and 60% of wild species have been collected (1987 study). Overall, global Triticum accessions consist of 3% wild relatives, 18% landraces/old cultivars, 19% advanced cultivars/breeding lines and 60% mixed categories or unknown material (Appendix 2). Estimated coverage of diversity from the

WANA region is 90% each for bread and durum wheats and 40% for other cultivated *Triticum*. There are some gaps in existing wheat collections from threatened areas in Turkey and under-collected areas such as Eritrea.

**Safety duplication**

At CIMMYT, 50% of bread wheat and 66% of *Triticale* have been duplicated while at ICARDA, 41% of durum wheat is duplicated. The extent of reported duplication in non-CGIAR genebanks ranges between 7% at PGRC, Ethiopia and 100% at KYOPGI, Japan (Appendix 2).

**Documentation characterization evaluation**

No global database exists. CIMMYT is compiling the International Wheat Information System for Passport Data. CIMMYT has recently initiated a genotype based database on named wheats and related species called the Genetic Resources Information Package. Many evaluation data exist but are generally not easily accessible. The Global Wheat Genetic Resources Network, initiated in 1993, is expected to improve availability. A number of IARCs have carried out evaluation of wild relatives for pathogen resistance, stress tolerance and nutritional quality, e.g., *Agropyron* spp. for resistance to *Helminthosporum*, or *Triticum tauschii*[14] for resistance to several diseases. Core collections are not available, although one for hexaploid wheat landraces is under development.

**Utilization**

CIMMYT-improved germplasm has been distributed to at least 38 countries. Some 84% of varieties released in these countries contain CIMMYT germplasm (1986-90). In 1990, 40 million hectares were planted with wheat varieties originating from CIMMYT or CIMMYT-based NARS crosses. A further 20-25 million hectares were planted with varieties having CIMMYT germplasm ancestry. Wheat yields globally have doubled in the last 30 years. Dramatic increases in yield have been achieved in some areas such as Western Europe, but increases have been much lower in dryer areas such as the South/East Mediterranean (Figure A2.1). Most cultivated wheat varieties in the United States are closely related (can be traced to 74 ancestors). In developing countries, more and more area is planted to few varieties (see Chapter One). The inflow of landrace material into breeding programmes is disproportionately low: a recent survey of wheat breeders indicates that while advanced lines and CIMMYT cultivars are widely used in breeding, landraces used account for only 8% of inputs.[15]

**Wheat yields, globally and for selected regions** (metric tonnes per hectare)

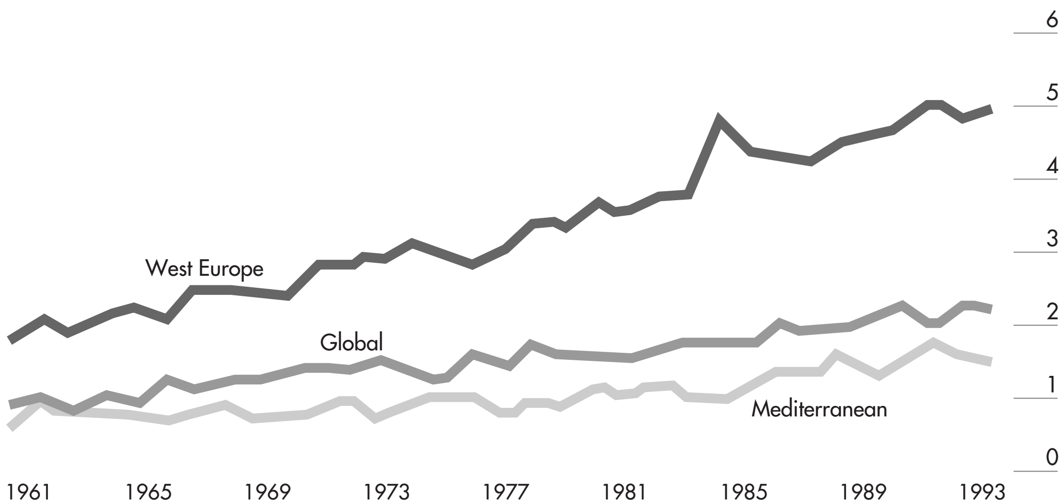



Figure A2.1 *Source:* FAOSTAT 1992/1993

## A2.2.2 State of rice genetic resources

**General**

Rice is the crop with the world's highest total production, 542 million tonnes (1995), cultivated over a harvested area of 149 million hectares. The five highest producers of rice are China (33% of global production), India (22%), Indonesia (9%), Bangladesh (5%) and Viet Nam (5%). Rice is extremely important to food security in Southeast Asia, East Asia, the Indian Ocean Islands, West Africa, the Caribbean and South America (Figure 1.3). The gene pool consists of two cultivated species *Oryza sativa* (subspecies *indica* and *japonica)* and *O. glaberrima* and about 20 species of wild rice and related genera.

***In situ* status**

Irrigated boro rices are replacing floating rices. Genetic erosion is reported in the Country Reports of China, the Philippines, Malaysia, Thailand and Kenya. Very few formal *in situ* programmes have been reported. Of these, on-farm conservation projects in the Philippines, Viet Nam and Sierra Leone are examples.

**_Ex situ_ collections**

The global collection consists of approximately 420,000 accessions. The largest holdings of rice, and the global base collection, are with IRRI in a particularly well-managed collection (19% of the global total). Of the ten largest rice collections, seven are stored under long- or medium-term conditions, and the status of the other three is not reported (Appendix 2).

**Coverage/gaps**

It has been estimated that 95% of landraces and 10% of wild species have been collected (1987). Overall, global rice accessions consist of 1% wild relatives, 25% landraces/old cultivars, 9% advanced cultivars/breeding lines and 65% of mixed categories or unknown material (Appendix 2). There are gaps in existing rice collections. Priority areas have been identified for *O. sativa* in Madagascar, Mozambique, South Asia and Southeast Asia and for related wild species from Brazil. However, cultivated species are very well collected.

**Safety duplication**

At IRRI, 77% of *O. sativa*, 54% of *O. glaberrima* and 65% of wild relatives have been duplicated. For several countries, such as Sri Lanka, Cambodia, and the Philippines, the germplasm conserved at IRRI represents an almost complete duplication of their national collection.

**Documentation characterization evaluation**

No global database exists and many characterization data are not easily accessible. USDA rice documentation information is now accessible through the Internet. IRRI and WARDA has computerized documentation systems. IRRI's International Rice Genebank Collection Information System accommodates passport, characterization and evaluation descriptors. At IRRI, passport data are only available for 20% of the *O. sativa* accessions, but are more complete for the accessions of *O. glaberrima* and wild relatives (68-69%). IRRI has conducted a preliminary evaluation of all of its germplasm for morphological and agronomic characters. The IRRI collection is particularly well evaluated for biotic and abiotic stresses, and core collections are being established for special purposes.

## Utilization

There have been dramatic increases in rice (*Oryza sativa*) yield since 1960 in several regions, such as East Asia. Yield increases in other regions such as the Indian Ocean Islands have been less dramatic (Figure A2.2). Much of the yield increases can be traced to the introduction of dwarfing genes and to the increased use of fertilizer, irrigation water and other inputs. Recently, yield increases have been diminishing and are increasingly difficult to achieve. Resistance genes from wild relatives have been extensively used, but breeders are generally not making full use of the existing rice collections. Although IRRI breeders have successfully incorporated successive genes for pest and disease resistance, the material is still based on the same semi-dwarfism and cina cytoplasm.[16] Crosses between *indica* and *japonica* subspecies and those between wild relatives and cultivated types are difficult. There are few improved deep-water rice varieties with increased tolerance to submergence, salinity and acidity and a paucity of improved germplasm for non-irrigated rice ecosystems. Such improved germplasm has not had much impact in farmers' fields. Hybrid rice development is in the initial stages, especially in China and India. IRRI is developing breeding lines of a new rice plant with higher grain biomass but finished varieties are not expected until after the year 2000.[17]

**Rice yields, globally and for selected regions** (metric tonnes per hectare)

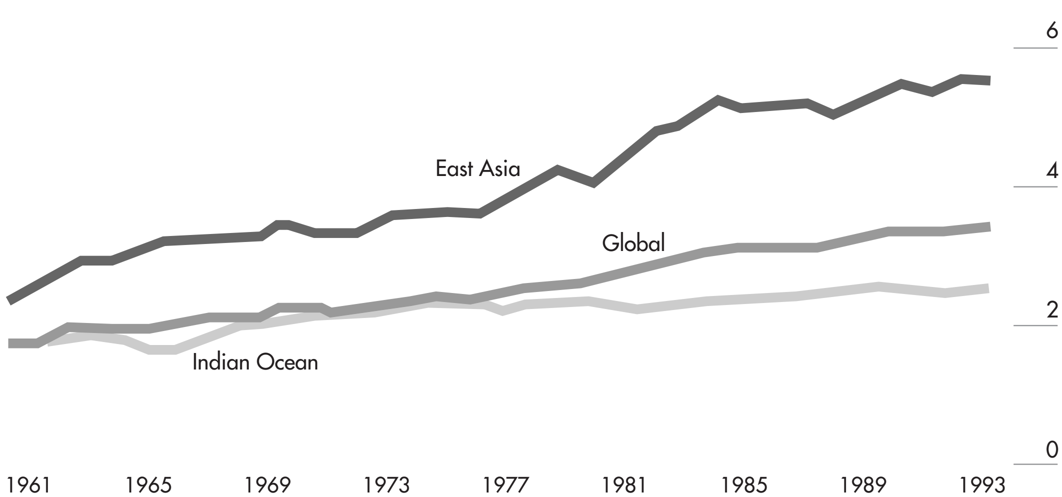



Figure A2.2 *Source:* FAOSTAT 1992/1993

## A2.2.3 State of maize genetic resources

**General**

Maize is grown over a harvested area of 130 million hectares with a global production of 502 million tonnes (1995). The five highest producers of maize are the United States (38% of global production), China (21%), Brazil (7%), Mexico (3%) and France (2%). Maize is particularly important to food security in Central and South America and most regions in Africa (Figure 1.3). The gene pool consists of one main cultivated species *Zea mays* and several related wild genera (*Zea diploperennis* and *Tripsacum* spp.).

***In situ* status**

Changes in cropping systems and urbanization are causing erosion. Country Reports indicate erosion in Mexico, Costa Rica, Chile, Malaysia, the Philippines and Thailand. Landraces account for about 40% of maize areas in developing countries in general, but in some cases it is as high as 80%, as in Costa Rica and Colombia. Very few formal *in situ* programmes have yet been reported. In Mexico, an i*n situ* conservation programme of teosinte has been established in a biosphere reserve and on-farm conservation using traditional cropping practices is being studied.

***Ex situ* collections**

There are an estimated 277,000 accessions worldwide. The genebank IARI-Maize (India) holds the largest collection (10% of global total), followed by VIR (Russian Federation) with 7% and NSSL in the United States with 5%. CIMMYT maintains the global base collection (5%). These are maintained under long-term conditions, except for the VIR collection, which is under medium-term storage. (Appendix 2).

**Coverage/gaps**

It has been estimated that 95% of landraces and 15% of wild species have been collected (1987). Overall, global maize accessions are reported to consist of very few wild cultivars, 17% landraces/old cultivars, 11% advanced cultivars/breeding lines and 65% mixed categories or unknown material (Appendix 2). There are gaps in existing collections, especially of Caribbean and Central American germplasm, and perhaps in Africa where an assessment of the extent of diversity is needed.

**Safety duplication**

At CIMMYT 80% of the collection has been duplicated (see Appendix 2).

**Regeneration needs**

The Latin American Maize Programme regenerated over 3,000 accessions, but there are continuing regeneration needs in many Latin American national genebanks because of poor storage conditions.

**Documentation characterization evaluation**

Information is available for maize accessions in Latin America in electronic format, but there is no global database. Many accessions have not been evaluated or adequately documented and no core collections are reported. More evaluation and characterization of accessions is needed to enhance the movement of stored germplasm materials into breeding programmes.

**Utilization**

About half of the world's maize production is in North America where high yields have been obtained (Figure A2.3) from the use of hybrids combined with ample inputs. However, the economic circumstances of farmers and the lack of the infrastructure necessary for the success of hybrids has meant that open-pollinated populations are predominant in most developing countries (e.g. in Southern Africa). Germplasm from CIMMYT's genebank has contributed to about 75% of 842 open pollinated and hybrid varieties released by breeding programmes in 45 developing countries. Out of 25 million hectares planted with improved seed in non-temperate areas, 13.5 million hectares were planted with open pollinated varieties or hybrids containing germplasm from CIMMYT. Teosinte and *Tripsacum* have so far not been widely utilized in maize breeding programmes. Landraces were intensively used in the 1940s and 1950s and provided the basis for the current elite material. Maize breeders in general no longer use accessions in germplasm collections when improved germplasm is available. CIMMYT is now turning to pre-breeding of enhanced maize germplasm which was provided to 45 countries in 1994. However greater efforts are required to improve disease resistance of maize varieties released in tropical environments. All commercial United States hybrids are mainly derived from six inbred lines.[18] The Germplasm Enhancement of Maize Collaborative Project has been established to broaden the genetic base of maize breeding programmes in the United States.

**Maize yields, globally and for selected regions** (metric tonnes per hectare)

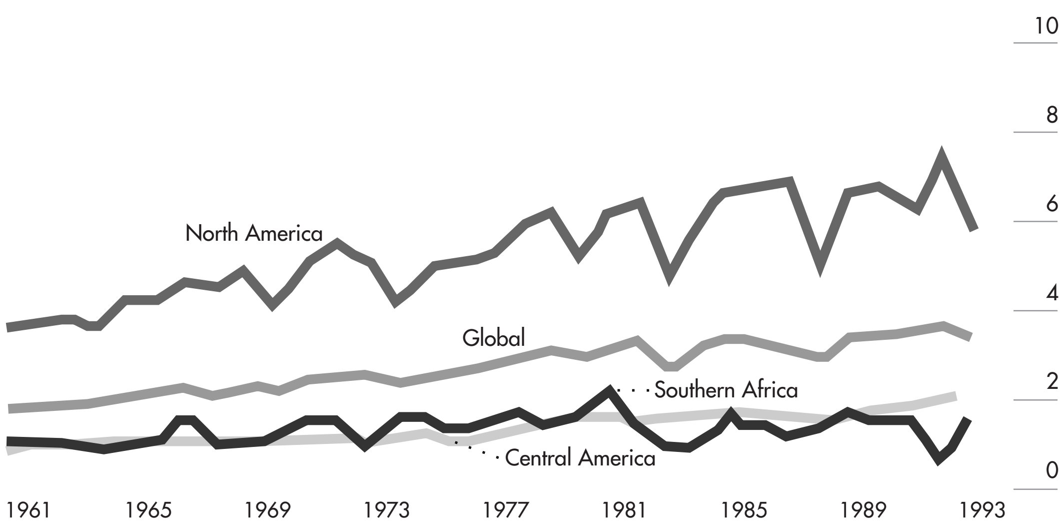



Figure A2.3 *Source:* FAOSTAT 1992/1993

## A2.2.4 State of sorghum genetic resources

**General**

Sorghum is cultivated over a harvested area of 43 million hectares with a global production of 54 million tonnes (1995). Sorghum is mainly for human consumption in Africa and India, and for animal feed in the United States and China. The five highest producers of sorghum are the United States (22% of global production), India (21%), China (11%), Nigeria (7%) and the Sudan (7%). Sorghum is important to food security in South Asia and particularly in Africa (Figure 1.3). The gene pool consists of 20 known species including *Sorghum bicolor, S. guinea, S. durra* and *S. caudatum.*

***In situ* status**

Genetic erosion was reported in the Sudanese Country Report. Among the few reported examples of *in situ* conservation programmes is a NGO on-farm conservation project for sorghum landraces in Zimbabwe.

**_Ex situ_ conservation**

Global collections consist of approximately 168,500 accessions with the largest collection (21% of global total) held in ICRISAT (Appendix 2). At ICRISAT 20% of the sorghum collection is stored under long-term conditions and 80% under medium-term conditions. Three of the remain-ing nine largest genebank collections are stored under long-term conditions, one collection is stored under medium term, three under short term and the status of two is unreported.

**Coverage/gaps**

It has been estimated that 80% of landraces and 10% of wild species have been collected (1987). Overall, global sorghum accessions consist of very few wild relatives, 18% landraces/old cultivars, 21% advanced cultivars/breeding lines while 61% is of mixed categories or unknown material (Appendix 2). A collaborative collection effort in Australia has added many distantly related wild sorghums to the ICRISAT collection, however, gaps in the wild and weedy accessions coverage still remain. ICRISAT has identified priority areas for collecting including Indonesia, the Philippines, the Commonwealth of Independent States (CIS) of the former Soviet Union, China, Pakistan, Benin, Chad, Côte d'Ivoire, Eritrea, Mozambique, Haiti, Guatemala, El Salvador and Nicaragua.

**Safety duplication**

41% of the ICRISAT sorghum collection and 11% of the PGRC-E (Ethiopia) collection are duplicated (Appendix 2).

**Documentation characterization evaluation**

No global database exists. Characterization data with passport information are documented electronically in ICRISAT with 83% of the collection documented for important morpho-agronomic descriptors. No core collections are reported.

**Utilization**

Current modern varieties have not been widely popular for human food. Breeders' attention is now increasingly focused on traits such as grain quality, photosensitivity and tolerance to biotic stresses.

**Sorghum yields, globally and for selected regions** (metric tonnes per hectare)

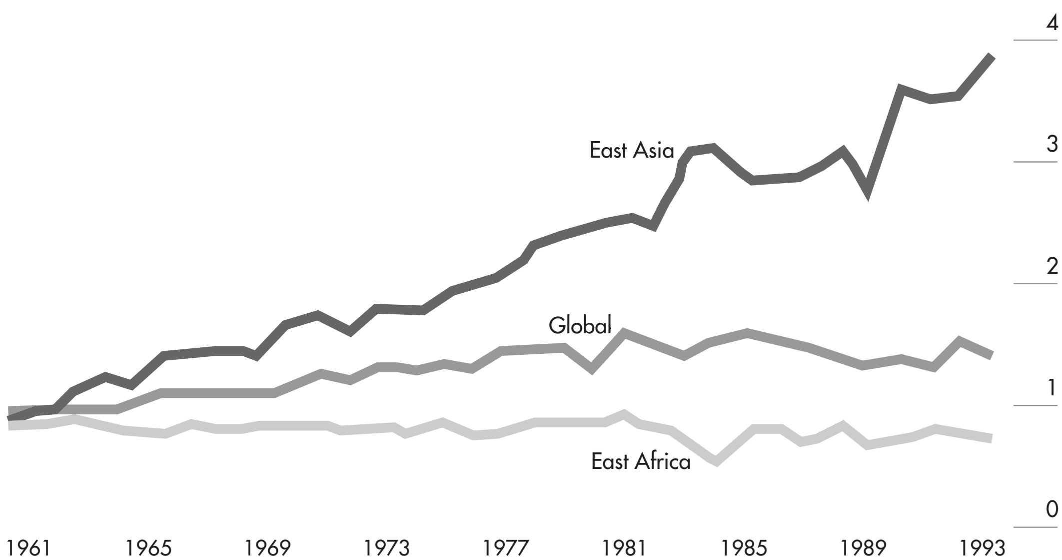



Figure A2.4 *Source:* FAOSTAT 1992/1993

Tropical sorghum is expected to be improved not solely for yield potential but also to obtain regular stable production with average yields adapted to cropping systems and user preferences.[19] The sorghum conversion programme in the United States allowed the utilization of previously unadapted tropical germplasm.[20] Another introgression and conversion project in sorghum was initiated in 1976 at ICRISAT. Exotic germplasm, mainly selected landraces from Ethiopia and the Sudan, were back-crossed to adapted cultivars to allow easy transfer of desirable traits. New sorghum cultivars and hybrids have produced dramatic yield increases in East Asia and in the United States (1-2% annual yield increase),[21] but yield increases have been much lower, or non-existent, in East Africa and South Asia (Figure A2.4).

## A2.2.5 State of millet genetic resources

**General**

Millets are grown over a harvested area of 38 million hectares with a global production of 26 million tonnes (1995). They are often dual-purpose crops (human consumption and animal feed) and are important staple foods in Africa and India (Figure 1.3). Millets are generally tolerant of poor soils, low rainfall and high temperatures and are quick maturing. The highest producers are India (39% of global production), Nigeria (13%), China (13%), the Niger (6%), Mali (3%) and the Sudan (3%). Millets include the major millet, pearl millet (*Pennisetum* spp.), and minor millets such as finger millet (*Eleusine coracana*), Japanese barnyard millet (*Echinochloa frumentacea*), common millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*).

***In situ* status**

No examples of *in situ* conservation programmes have been reported for millets.

***Ex situ* conservation**

The global collection of millets is estimated to consist of 90,500 accessions. The major holding of *Pennisetum* is at ICRISAT (58% of global total of pearl millet); *Eleusine* at the University of Agriculture, India (31% of *Eleusine*) and *Setaria* at ICGR, China (19% of *Setaria*). Of all millet collections, 100% of two collections (NSSL in the United States and ICGR-CAAS in China) and 20% of ICRISAT's, are conserved under long-term conditions. Nine other collections and 80% of ICRISAT's are stored under medium-term conditions. The largest *Eleusine* collection and two significant collections of *Pennisetum* and *Setaria* are under short-term storage. The storage status of two of the larger collections is unknown (Appendix 2).

**Coverage/gaps**

It has been estimated that 80% of landraces and 10% of wild species of pearl millet; and 45-60% of landraces and 2-10% of wild species of other millets have been collected (1987). Overall, global millet accessions consist of 2% wild relatives, 33% landraces/old cultivars, 5% advanced cultivars/breeding lines and 60% unknown and mixed (Appendix 2). There are gaps in existing collections. Priority areas for collecting have been identified by ICRISAT and include Benin, Chad, Guinea-Bissau, Côte d'Ivoire and Mauritania for pearl millets, and India, CIS, United Republic of Tanzania and Rwanda for minor millets.

**Safety duplication**

At ICRISAT, 25% of the pearl millet and 4% of minor millet collections are duplicated. The extent of reported safety duplication in non-CGIAR genebanks ranges from 4 to 100% (Appendix 2). No systematic effort has been made for safety duplication.

**Documentation characterization evaluation**

No global database exists. Approximately 72% of the ICRISAT millet accessions have been documented for important agronomic descriptors. Characterization data with passport information have been electronically documented. However, wild species need to be characterized. No core collections have been reported.

**Millet yields, globally and for selected regions** (metric tonnes per hectare)

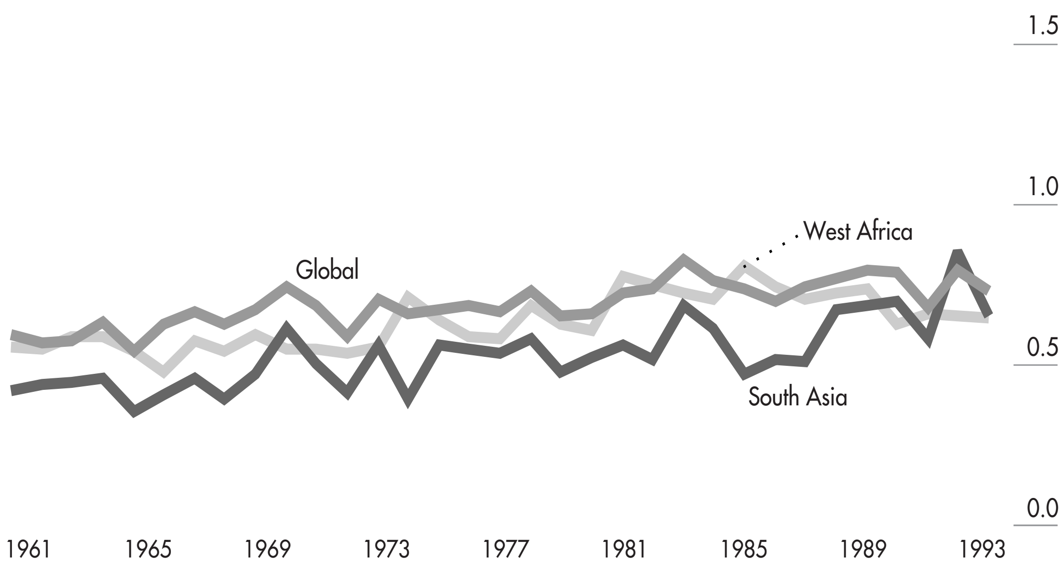



Figure A2.5

*Source:* FAOSTAT 1992/1993

**Utilization**

At a global level, yields of millet have not substantially increased since the 1960s and in some regions yields have been declining in recent years (Figure A2.5). More than a third of the area cultivated in India is now planted with improved millet varieties that originate from ICRISAT.

## A2.2.6 State of cassava genetic resources

**General**

Cassava (*Manihot esculenta*) is grown over a harvested area of 16 million hectares with a global production of 161 million tonnes (1995). Cassava is one of the most efficient crops in biomass production. In comparison with many other crops, it excels, under sub-optimal conditions and can withstand drought conditions. The five highest producers of cassava are Brazil (16% of global production), Nigeria

(13%), the Democratic Republic of Congo (11%), Thailand (10%) and Indonesia (10%). Cassava is essential to food security in most regions of Africa (Figure 1.3). The genepool consists of the cultivated *M. esculenta* and at least 80 wild *Manihot* species.

***In situ* status**

The threat of erosion from agricultural expansion has been reported by countries in the tropical lowlands of the Americas, and from single cultivar based monocultures in Thailand and China. At least 7,000 landraces of cassava are estimated to exist. No examples of *in situ* conservation programmes have been reported.

***Ex situ* conservation**

There are 28,000 accessions of cassava in collections worldwide. Very few countries have *ex situ* collections of cassava. The largest collections include those as CIAT (21% of global total). Other large collections are at IITA (8%), ICAR, India (5%) CNPMF, Brazil (5%) and SAARI, Uganda (4%). CIAT has a mandate for cassava germplasm in Asia and Latin America and IITA for African germplasm. CIAT maintains the world cassava collections both in the field and *in vitro*.[22] CNPMF has a field collection with 25% of its total stored *in vitro*. Approximately 100% and 21% of the CIAT and IITA collections, respectively, are also under *in vitro* storage (Appendix 2).

**Coverage/gaps**

It has been estimated that 35% of landraces and 5% of wild species have been collected (1987). Estimated gene pool coverage of the CIAT collection in South America of *M. esculenta* is 70% and ranges between 0 and 5% for the wild species. Overall, global cassava accessions consist mainly of landraces and old cultivars. CIAT's collection of *M. esculenta* contains 87% landraces and traditional varieties, the remainder being lines and genetic stocks. CIAT also holds accessions of 23 *Manihot* species. IITA's collection consists of 55% advanced cultivars, 33% landraces and 11% wild and weedy relatives. There are gaps in existing cassava collections and most collecting efforts have concentrated on landraces. Priority areas for collecting have been identified in Latin America (Honduras, Nicaragua, Dominican Republic), the Caribbean (Haiti) and Africa (Democratic Republic of Congo, Nigeria and Angola). Collecting in Southeast Asia and the Pacific is considered a secondary priority.

**Safety duplication**

At CIAT, 81% of the cultivated collection has been duplicated informally (outside of formal arrangements), while at IITA 15-21% of the cultivated and 100% of the wild germplasm is safety duplicated.

**Documentation characterization evaluation**

There is no global database, but a uniform database is under development in Latin America. Passport data for CIAT's collection are relatively complete for only some of the accessions, but 90% of the collection has been characterized. Isozyme and DNA characterization has been used to fingerprint 4,300 accessions. Passport data are available for only 8% of IITA's collection, of which 46% has been characterized. A core collection has been developed in CIAT.

**Utilization**

There have been moderate yield increases in cassava at the global level since 1961, but in some regions (Central Africa), yields have consistently remained below the global average (Figure A2.6).

**Cassava yields, globally and for selected regions** (metric tonnes per hectare)

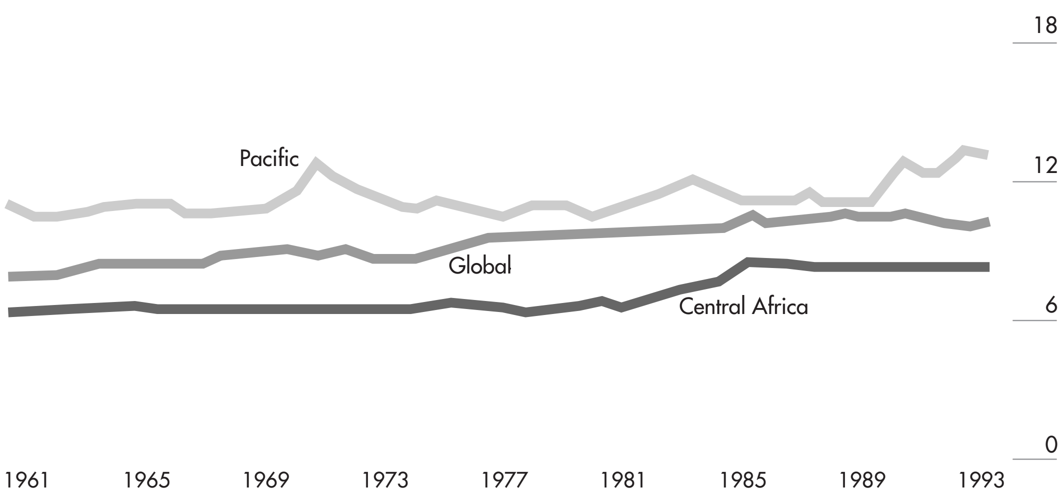



Figure A2.6 *Source:* FAOSTAT 1992/1993

Compared to other important crops, it has received little research support.[23] Virtually all formal improvement efforts are being undertaken by the public sector. There is need to broaden the genetic base of cassava through increased use of wild relatives.[24] The Cassava Biotechnology Network and the Manihot Genetic Resources Network are planning to characterize and rationalize the cassava germplasm collections held by several countries in South America. In Africa, IITA, the Regional Research Project for Maize and Cassava, and the East and South African Root Crops Research Network all perform research on the improvement of cassava. Some West African countries conduct research on cassava improvement as part of Coraf/ Resau Manioc. There are also cassava breeding programmes in South America and Asia. IITA has identified and distributed clones resistant to African cassava mosaic virus and bacterial blight disease. Since 1981, 47 varieties have been released by the CIAT cassava breeding programme, of which 21 were landraces evaluated as promising cultivars.

## A2.2.7 State of potato genetic resources

**General**

Potato is cultivated over a harvested area of 19 million hectares with a global production of 275 million tonnes (1995). The five highest producers are China (16% of the global production), the Russian Federation (12%), Poland (8%), the United States (7%) and India (7%). Potato is important to food security particularly in America (North and South) and Europe (Figure 1.3). The gene pool consists of cultivated *Solanum* spp. such as *Solanum tuberosum* ssp. *andigena* and *tuberosum*; *S. stenotomum, S. ajanhuiri, S. goniocalyx, S.* x *chauca, S.* x *juzepczukii, S.* x *curtilobum* and *S. phureja*. There are also about 200 wild tuber-bearing *Solanum* spp. of which about 60% are located in Peru and Bolivia.

***In situ* status**

Genetic erosion is reported in the primary centres of origin, such as Chile and Bolivia. In Peru, of the 90 wild potato species that have been described, 35 are no longer found in the wild. On-farm conservation projects are reported in Colombia and Bolivia. There is a need to determine existing microcentres of diversity.

***Ex situ* conservation**

There are 31,000 accessions of potato in collections worldwide, with 20% held by CIP. Other large collections are in the genebanks ICA-Region 1, Colombia (11%); HNA, Japan (6%), ROPTA, the Netherlands (5%), PGQC, the

United States (5%) and HBROD, the Czech Republic (4%). The CIP collection is under medium-term *in vitro* storage conditions and the Colombian collection is under short-term storage. The collections of the Czech Republic and the United Kingdom are also stored *in vitro*. True seed is also stored in seed genebanks. Globally, 20% of accessions are in medium-term storage, 11% in short-term and 69% unknown (Appendix 2).

**Coverage/gaps**

It has been estimated that 95% of landraces and 40% of wild species have been collected (1987). The CIP potato collection is the most diverse, containing 59% landraces/old cultivars, 16% advanced cultivars and 25% wild and weedy relatives. Collections of wild potatoes are also found in the United States and Europe. Other major collections contain mainly advanced cultivars, e.g. Czech Republic (94%) and Poland (100%). Overall, global potato accessions consist of 5% wild relatives, 12% landraces/old cultivars, 19% advanced cultivars/breeding lines and 63% mixed or unknown material (Appendix 2). There are gaps in existing potato collections, particularly of wild potato species. A survey of wild potato holdings in the largest important genebanks in the United States and Europe, and at CIP, showed that few wild species are adequately sampled throughout their geographic area of distribution.

**Safety duplication**

At CIP, 100% of the Andean cultivars collection has been duplicated. The extent of safety duplication for other genebanks is not reported, but there are problems at CIP with regeneration of true potato seed.

**Documentation characterization evaluation**

There is no global database. Germplasm collected outside Peru can only be characterized/evaluated at CIP after passing quarantine regulations. So far, 1373 accessions from CIP have been characterized. CIP and NARS have conducted 48,000 evaluations of native potato cultivars to biotic and abiotic stresses. All data are held in a computerized documentation system at CIP; data are also available in other potato genebanks.

**Utilization**

There have been spectacular yield increases in potato in Western Europe since 1961, which are partly the result of a concerted base-broadening programme begun in the 1960s.[25]

At a global level and in some regions, for example in South America, yield increases have been much lower (Figure A2.7). A large amount of diversity is available to breeders and demand for material from CIP is increasing as the number of pathogen-tested accessions increases. In 1994, CIP distributed potato germplasm to researchers in more than 60 countries. Existing commercial potato varieties are susceptible to a new race of *Phytophthora infestans* and wild species and Andean cultivated potatoes are being evaluated for resistance. Potato represents one of the best examples of utilization of wild species and primitive cultivars in plant breeding. About 20% of the crosses made at CIP between 1972 and 1986 included wild species or native cultivars as one or both progenitors. Although wild potato species have been utilized primarily as a source of genes contributing disease resistance, they have also contributed cytoplasmic male sterility, frost resistance, yield and starch content. CIP makes extensive use of the genetic resources in *Solanum*.

**Potato yields, globally and for selected regions** (metric tonnes per hectare)

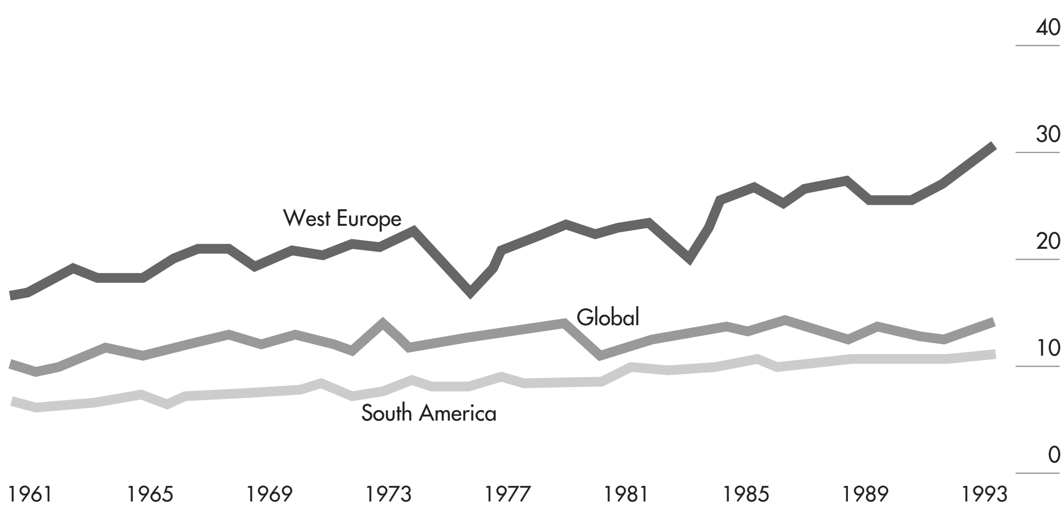



Figure A2.7 *Source:* FAOSTAT 1992/1993

## A2.2.8 State of sweet potato genetic resources

**General**

Sweet potato (*Ipomoea batatas)* is cultivated over a harvested area of 10 million hectares with a global production of 127 million tonnes (1995). The five highest producers of sweet potato are China (85%), Viet Nam (2%), Uganda (2%), Indonesia (2%) and India (1%). Sweet potato is important to food security particularly in Africa (West, East and Central), the Caribbean and the Indian Ocean Islands. Besides the cultivated species, the gene pool also includes about 400 recognized wild *Ipomoea* species in the Americas.

**_In situ_ status**

In the Americas, more than 300 different wild *Ipomoea* spp. exist, and the extent of their genetic erosion is unknown. In countries where sweet potato breeding programmes exist, improved varieties are known to have replaced native cultivars. In Peru, modern varieties such as Nemanete, Maria Angola and Japones Tresmesino, have replaced native cultivars. No formal *in situ* programmes have been reported in the Country Reports.

**_Ex situ_ conservation**

There are approximately 32,000 accessions stored in genebanks worldwide, with 21% held by CIP. Other large collections are found in the genebanks of AVRDC (4%); USVL, the United States (4%); HAES, Papua New Guinea (4%) and IBKNA and UCDKNAE, Japan (8%). Most of CIP's accessions are under medium-term *in vitro* storage and in field genebanks (Appendix 2). Seed of wild species is generally stored under medium-term conditions. USDA also has an *in vitro* collection. Most national collections are in field genebanks, many of which are short of funds.

**Coverage/gaps**

It has been estimated that 50% of landraces and 1% of wild species have been collected (1987). CIP's collection contains 59% landraces/old cultivars, 23% advanced cultivars and 18% wild and weedy relatives. Overall, global sweet potato accessions consist of 6% wild relatives, 16% landraces/old cultivars, 13% advanced cultivars/breeding lines and 65% mixed categories or unknown material (Appendix 2). There are gaps in existing sweet potato collections. According to CIP, samples of native cultivars need to be collected in the secondary centres of diversity in Africa and Southeast Asia. Collections outside Latin America mainly contain cultivars from Southeast Asia.

**Safety duplication**

CIP has duplicated 93% of its collection. The extent of safety duplication for other genebanks is not reported.

**Sweet potato yields, globally and for selected regions** (metric tonnes per hectare)

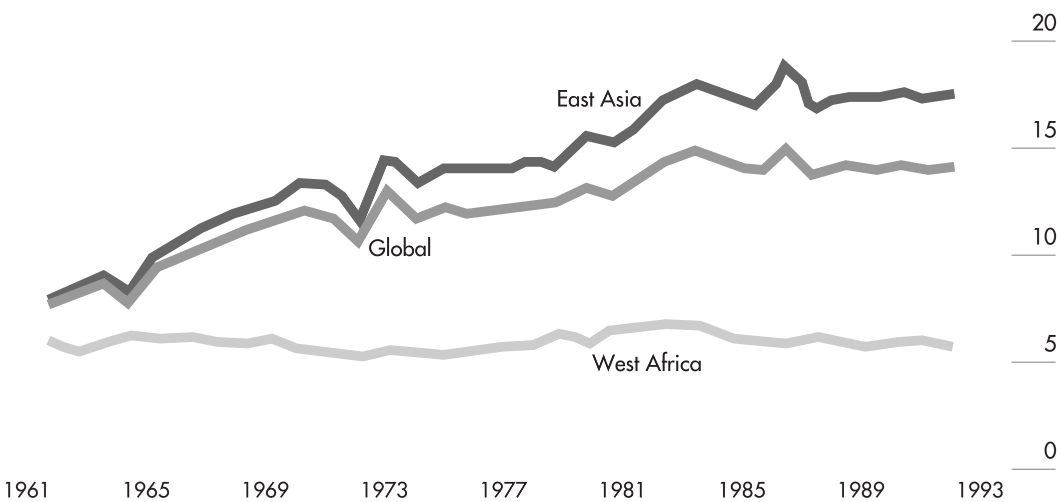



Figure A2.8 *Source:* FAO STAT 1992/1993

**Documentation characterization evaluation**

There is no global database. CIP's collection has been extensively characterized and systematically evaluated. An estimated 13,000 accessions have been evaluated, many of which have been identified as potential sources of useful genes. All the data are available in a computerized documentation system. Improvement of phytosanitary facilities at CIP could facilitate more thorough evaluation of the collection.

**Utilization**

There have been spectacular yield increases at the global level and in East Asia particularly. Nevertheless, yield increases in many regions where sweet potato is a staple, for example, in West Africa, have been practically non existent (Figure A2.8). In the last 10 years, sweet potato varieties have been released by NARS from material selected from native cultivars or produced by breeding methods using parents from germplasm collections. While CIP performs pre-breeding work, a wider use of wild species and native cultivars is limited by the low level of pre-breeding work outside CIP.

## A2.2.9 State of banana/plantain (*Musa* spp.) genetic resources

**General**

Bananas and plantains are each grown over harvested areas of 5 million hectares, 10 million hectares in total, with a global production of 56 million and 30 million tonnes, respectively (1995). The five largest producers of banana are India (18% of global production), Brazil (11%), Ecuador (9%), the Philippines (6%) and China (6%). For plantain the largest producers are Uganda (32%), Colombia (10%), Rwanda (9%), the Democratic Republic of Congo (8%) and Nigeria (5%). Bananas/plantain are important to food security in Africa (West, East and Central) and the Caribbean (Figure 1.3). The *Musa* gene pool encompasses wild species and edible bananas and plantains.

***In situ* status**

The primary centre of origin is in Southeast Asia. Most diversity in edible diploid (AA) bananas is now considered to be in Papua New Guinea. Secondary centres of diversity are in East and Central Africa, the Indian Ocean Islands and the Pacific.

***Ex situ* conservation**

There are approximately 10,500 accessions stored in genebanks worldwide, with 10% held by INIBAP. Other major collections are at - CIRAD, France (9%), FHIA, Honduras (9%), BPI, the Philippines (6%) and DPI, Papua New Guinea (5%). The INIBAP collection contains 77% landraces and old cultivars, 7% advanced cultivars and 15% wild species. INIBAP's collections are maintained *in vitro* and duplicated in the field. Other collections are mainly in the field. A reliable method for detecting somaclonal variation *in vitro* is not available.

**Coverage/gaps**

Extensive collecting has taken place in Southeast Asia, and parts of Africa. At present it is thought that the INIBAP collection covers most of the known diversity of wild and cultivated bananas. Gaps in existing *Musa* spp. collections have been identified from Viet Nam, Papua New Guinea, South China, the Indian Ocean Islands, Myanmar and Northeast Asia. Although few new unique landrace cultivars have been found during the last decades, there is a need for further collecting in these areas.

**Safety duplication**

At INIBAP 39% of the collection is duplicated *in vitro* at the Taiwan Banana Research Institute, Taiwan Province of China.

**Documentation characterization evaluation**

There is no global database. INIBAP maintains a computerized database containing passport data, health status and storage information for all its accessions which is available through the Internet. Selected characterization data are also available.

**Utilization**

Bananas and plantains are vegetatively propagated and conventional breeding programmes have had limited success. Most efforts have been directed towards producing disease-resistant varieties suitable for the banana export market but in recent years plantains have also received attention. The number of *Musa* breeding programmes worldwide is very small and no commercially important varieties have yet been developed. Use of the INIBAP collection is limited to nearly 40% of the collection, as the remainder awaits virus indexing.

Export banana production relies heavily on a very narrow genetic base as all export bananas are of the Cavendish type. Production of banana and plantain for local consumption is based on a wide range of varieties.

## A2.2.10 State of genetic resources of common bean and related species (*Phaseolus*)

**General**

Dry beans[26] are grown over a harvested area of 27 million hectares with a global production of dry beans of 18 million tonnes in 1995 (excluding production from intercropped fields). The five highest producers are India (23%), Brazil (18%), China (11%), the United States (8%) and Mexico (7%). Beans are particularly important to food security in Central America and Africa (West, East and Southern), (Figure 1.3). The *Phaseolus* gene pool includes the cultivated species *P. vulgaris, P. lunatus, P. coccineus, P. polyanthus, P. acutifolius*, and related wild species.

**_In situ_ status**

*Phaseolus* genetic resources are reported to be under increasing threat of erosion by Costa Rica, Guatemala and Mexico. The Geographic Information System (GIS) is being used by CIAT to map areas of highest genetic diversity. Peru, Malawi and Zimbabwe have projects for landrace conservation.

**_Ex situ_ conservation**

There are approximately 268,500 accessions stored in genebanks worldwide, with 15% held by CIAT. Other large collections include W-6, the United States (4%);[27] INIFAP, Mexico (4%); NSSL (4%) and INIA-Iguala, Mexico (4%). Of the 10 largest collections, six are stored under long- or medium-term storage conditions, one is partially under long-term conditions, one is under short-term conditions and the conditions of storage are unknown for the remaining two. Of the CIAT collection, 50% is maintained under long-term storage conditions. Globally, 6% of collections are long-term, 21% medium-term, 5% short-term and 68% of mixed categories or unknown (Appendix 2).

**Coverage/gaps**

It is estimated, on average, that 50% of the diversity of the genus, including all species, is represented in the CIAT collection. These estimates range from 65% for cultivated common bean (*P. vulgaris*) to 0-40% for non-cultivated species. Overall, global *Phaseolus* accessions consist of 1% wild relatives, 21% landraces/old cultivars, 3% advanced cultivars/breeding lines and 76% mixed or unknown material (Appendix 2). Over 85% of CIAT's collection comes from other genebanks rather than its own collecting missions. CIAT has 41,061 accessions, mostly (97%) landraces. Of the total collection at CIAT, 90% is *P.vulgaris* (common bean), 5% is *P. lunatus* (lima bean), 2% is *P. coccineus* (scarlet runner bean), 1% is *P. polyanthus* (year bean), almost 1% is *P. acutifolius* (tepary bean) and approximately 0.6% is wild species. There are gaps in existing *Phaseolus* collections, especially of wild species. Diversity is not adequately represented in the genebanks. Field inventories and collections in secondary centres (Mediterranean, Near East, Eastern Africa, China) are incomplete.

**Safety duplication**

At CIAT, 79% of the *Phaseolus* collection is duplicated. Quarantine regulations can restrict movement of germplasm.

**Documentation characterization evaluation**

Development of a global database on *Phaseolus* genetic resources is needed. An estimated 65% of CIAT's collection has been evaluated for morpho-agronomic traits, and disease and pest resistance. Other major collections (United States, Mexico, Brazil) have also been extensively but not uniformly-evaluated. Core collections of common bean, defined at CIAT and in the United States using passport, ecoclimatic and molecular marker data, are increasingly used for evaluation and breeding.

**Utilization**

Globally and regionally, yields of dry bean have been on a plateau since the 1950s[28] (Figure A2.9). Extensive widecrossing has been done but has rarely resulted in the production of useful breeding lines. Stabilization of yields through breeding and selection is difficult because of the wide variation in consumer preferences for seed colour, shape, etc. Nonetheless, CIAT has developed several improved varieties that have been widely adopted by smallholder farmers. CIAT distributed 32,700 accessions of *Phaseolus* between 1992 and 1994. Between 1979 and 1994, 37 countries received 203 CIAT cultivars, of which 55 were directly selected from the germplasm collection without breeding. A considerable part of the edible dry bean area in the United States depends upon a dangerously small germplasm base.[29]

**Dry bean yields, globally and for selected regions** (metric tonnes per hectare)

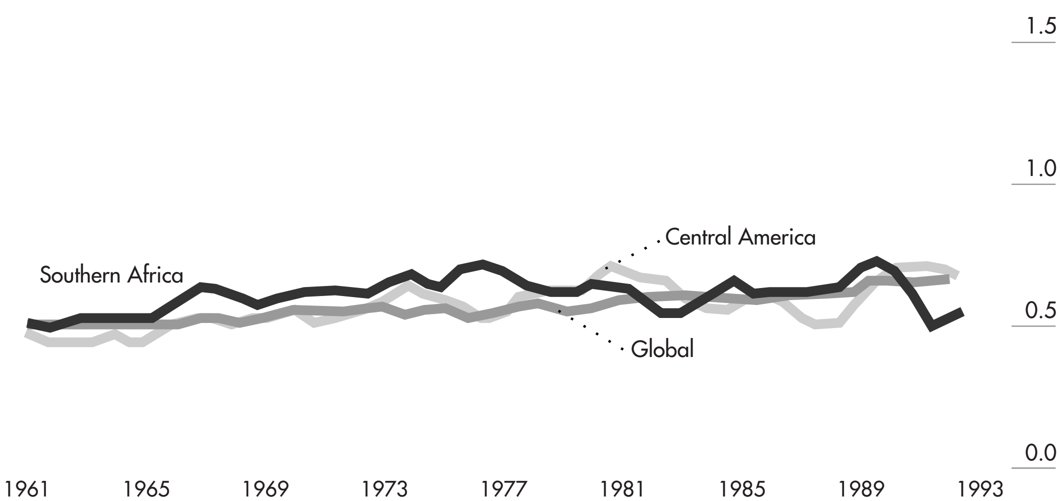



Figure A2.9 *Source:* FAO STAT 1992/1993

## A2.2.11 State of soybean genetic resources

**General**

Soybean is grown over a harvested area of 66 million hectares with a 1995 global production of 126,852,000 tonnes. The five largest producers of soybean are the United States (47%), Brazil (20%), China (11%), Argentina (11%) and India (4%). Soybean is a major contributor of human calorie intake in the Americas, Europe, the Caribbean and the Pacific (Figure 1.3). The soybean gene pool consists mainly of the cultivated species *Glycine max* and related wild species.

***In situ* status**

No reports on *in situ* soybean status were received by the ITCPGR preparatory process.

***Ex situ* collections**

There are 174,500 accessions stored in genebanks worldwide, with 9% held in ICGR-CAAS in China. Other large collections are found in AVRDC (7%), NSSL, United States (6%), SOY-N, United States (5%)[30] and IAB, Ukraine (4%). Of the ten largest collections, four are reported to be under long-term storage conditions, three under medium-term, and one under short-term conditions. Globally, 24% of accessions are under long-term storage conditions, 25% medium term, 8% short term, and 42% are unknown (Appendix 2).

**Coverage/gaps**

It has been estimated that 60% of landraces and 30% of wild species have been collected (1987). Overall, global soybean accessions consist of 1% wild relatives, 2% landraces/old cultivars, 7% advanced cultivars/breeding lines and 91% mixed or unknown material (Appendix 2). Much genetic diversity of *G.max* remains uncollected in eastern and southern Asian countries (e.g. China, Democratic Peoples Republic of Korea, Russian Federation, Republic of Korea, Japan, Cambodia, Myanmar, Afghanistan).

**Safety duplication**

The safety duplication status of many of the largest collections is not reported, although 100% of the SOY-S (United States) and 47% of the IITA collections are duplicated. China lacks funds for multiplication of sufficient quantities of seed to meet demand for germplasm exchange or duplication.[31]

**Documentation characterization evaluation**

There is no global database and little reported information on the extent of documentation and characterization. Older accessions of the United States soybean collection have been evaluated for a number of traits and information is accessible through publications and the Internet. China lacks funds to fully evaluate their valuable collection. IITA's soybean collection has been evaluated for several agronomic traits but the information has not been systematically documented.

**Utilization**

There have been substantial yield increases globally and in North America, but yield increases have been much lower in other areas such as Southeast Asia (Figure A2.10).

**Soybean yields, globally and for selected regions** (metric tonnes per hectare)

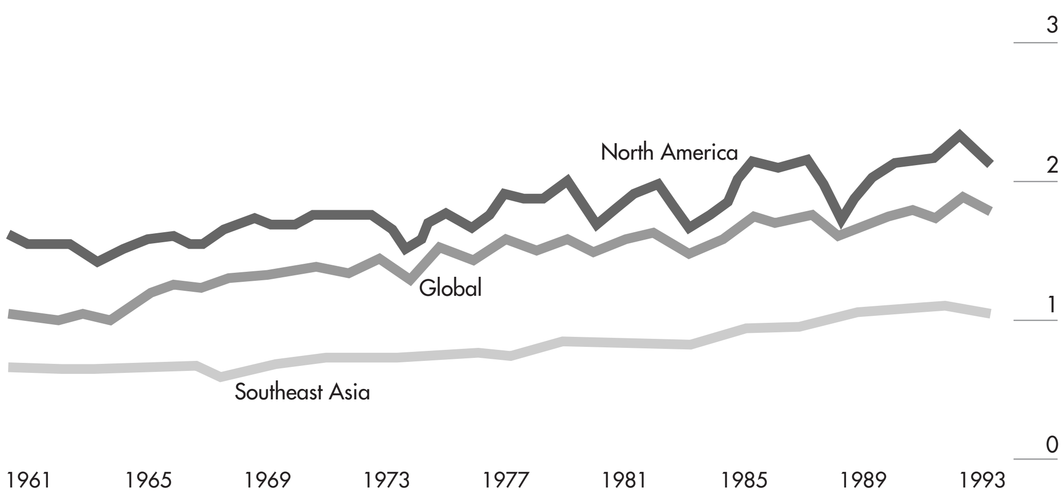



Figure A2.10 *Source:* FAO STAT 1992/1993

Germplasm utilization is lagging behind germplasm conservation. Genebank accessions have been successfully used to improve disease and insect resistance, plant morphology, and seed composition, but the collections have not been used well for quantitatively inherited traits such as seed yield, and oil and protein percentage of the seed. Compared to other CGIAR mandated crops, there is little international co-operation in germplasm research in soybean although IITA's breeding programme does collaborative evaluation work with NARs in Africa, the United States, and with AVRDC. The genetic base of varieties is narrow worldwide. Over 25% of the genetic base of United States soybeans trace back to five introductions.[32] In the United States, while the collection is used mainly for qualitative trait introgression, this has not substantially broadened the genetic base of soybean breeding.

### A2.2.12 State of sugar cane genetic resources

**General**

Sugar cane is cultivated over a harvested area of 18 million hectares with a total global production of 1,000 million tonnes (1995). The five largest producers of sugarcane are Brazil (26% of global production), India (22%), China (6%), Thailand (4%) and Pakistan (4%). Sugar[33] is a major contributor to human calorie intake in all regions except West and Central Africa (Figure 1.3). The sugar cane gene pool consists of the cultivated species *Saccharum officinarum, S. barberi, S. edule,* and *S. sinense.* Only *S. robustum* and *S. spontaneum* are wild species. Commercial varieties are from interspecific crosses among *S. barberi, S. edule, S. officinarum, S. robustum, S. sinense* and *S. spontaneum.* Related genera have been included in the *Saccharum* gene pool complex, such as *Erianthus, Imperata, Miscanthus, Narenga, Nephia, Neyrudia, Sclerostachya,* and *Vetiveria.*

***In situ* status**

Reported to be under severe threat from genetic erosion. In Assam (India) extensive monocrop plantations have replaced the indigenous species and similar replacement is expected to occur in Indonesia, Papua New Guinea and Thailand.

***Ex situ* conservation**

There are approximately 19,000 accessions stored in genebanks worldwide, with 24% held in CENARGEN, Brazil. Other large collections include SBI, India (21%); CR-MIA, United States (11%), Dominican Republic (10%) and EEC-INICA, Cuba (7%). Four of these five largest sugar cane collections (approximately 63% of global accessions) are maintained as field genebanks. (Appendix 2). The United States collection has suffered occasional neglect due to inadequate resources and is on a government closure list. The United States field collection was damaged by Hurricane Andrew.

**Coverage/gaps**

It has been estimated that 70% of landraces and 5% of wild species have been collected (1987). Overall, global sugar cane accessions are reported to consist of 10% advanced cultivars/breeding lines and 90% mixed or unknown material (Appendix 2) The *Saccharum* gene pool is considered to be fairly well represented in collections. There is a need to collect the wild species, and related genera and landraces of *S. barberi* and *S. sinense* which are still grown in remote areas. There are gaps in existing sugar cane collections from some regions of Pakistan, Bangladesh, Myanmar, Malaysia, Indonesia, Nepal, Viet Nam, China, India and Islamic Republic of Iran.

**Safety duplication**

The global collection is duplicated in India and the United States. The United States collection has now been largely replanted in Brazil.

**Documentation characterization evaluation**

There is no global database. Data on the United States collection are accessible by computer through the USDA's GRIN database. Indian collections have been largely characterized while those of the USDA collections are incompletely characterized. There is a lack of evaluation and no core collections have been established. The Indian collection is being evaluated for resistance to recently identified viruses.

**Utilization**

Globally and regionally, there has been no major yield increase in sugar cane since the 1960s[34] (Figure A2.11). Varieties are usually restricted to specific micro-environments due to high genotype by environment interactions. Plantations are especially subject to serious disease and pest problems. In general, use of the collections as a source of parents has been limited. It is estimated that 90% of germplasm movement between breeders is of elite breeding materials and 10% of wild germplasm. The cytoplasmic genome in five of the six species is remarkably uniform, making them potentially vulnerable genetically. A number of efforts are under way to broaden the genetic base of sugar cane. There is a base broadening programme in the West Indies. The most genetically diverse gene pool of *S. robustum* has had limited use in breeding.

**Sugar cane yields, globally and for selected regions** (metric tonnes per hectare)

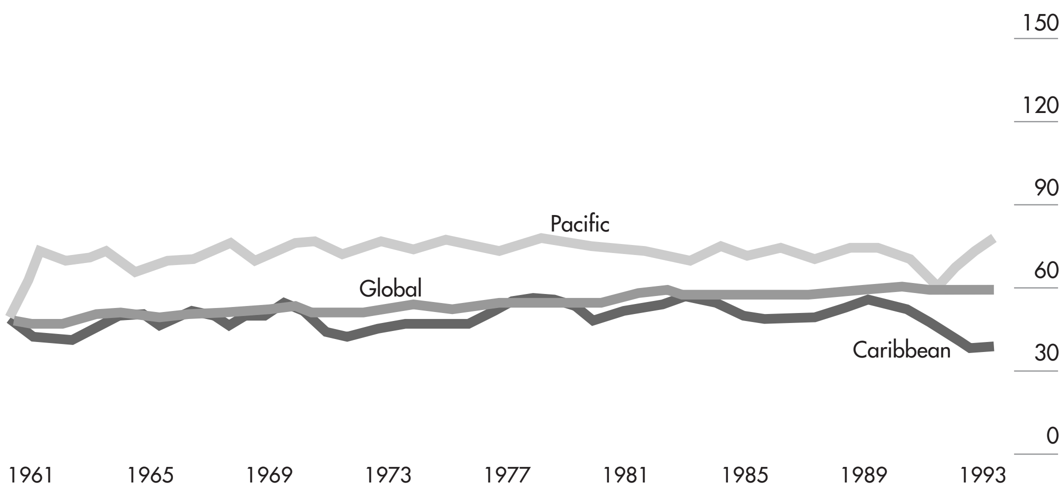



Figure A2.11

*Source:* FAO STAT 1992/1993

## A2.2.13 State of forages and rangeland crop genetic resources

**General**

Forages include a wide range of cultivated and wild species in the temperate and tropical areas such as fodder trees and shrubs, legumes, grasses and herbs. About 20 species of legumes are considered as important fodder crops at the global level.

***In situ* status**

Much diversity exists in the large grassy areas in the tropics and sub-tropics. Some large areas of natural grassland in Africa have been designated national parks for conservation of wildlife. However, there are severe threats to forage genetic resources in many rangelands due to rapid population growth and changing of pastoral practices leading to over-grazing and desertification.

***Ex situ* conservation**

Clover is the most frequently collected forage crop. In the case of fodder legumes, vetch, trefoil and rye, single institutions each hold 50% and more of total accessions. Wild species like rangeland grasses are collected in smaller amounts. The largest forage collections are BYDG, Poland (grasses); AGRESEARCH, New Zealand (clover and trefoil); CIAT (legumes); IHAR, Poland (fescue and *Phleum*); KNEAS, Japan (millet); IBEAS, France (pea); ICARDA (*Medicago* and vetch); and SVALOF, Sweden (rye) (Appendix 2).

**Coverage/gaps**

The estimated gene pool coverage rates for the largest collections cited above are grasses (12%), clover (13%), *Medicago* (26%), legumes (68%), fescue (19%), millet (13%), pea (27%), vetch (58%), *Phleum* (28%), trefoil (50%) and rye (82%). High levels of coverage are estimated for tropical highland forage legumes and arid/semi-arid African grasses (ILRI). Gaps are identified for marginal rangeland forages, frost-tolerant fodder trees in tropical highlands, species from temperate lowlands and highlands, and marginal areas in the Near East. Even where maps show good geographical coverage, there is still poor ecological coverage, with only one grassland type (intensive permanent grassland) dealt with typically.

**Safety duplication regeneration**

Approximately 41% of legumes and 57% of grasses at CIAT are duplicated for safety, and 74% of forages at ILRI. There is now a need to regenerate 2,000 of the forage accessions at ILRI.

**Documentation**

Basic passport data are available at ICARDA (complete information for 25% of accessions), including distribution of samples, and short information for 85% of accessions at CIAT. At ILRI, passport, inventory, regeneration and germination data are recorded. Documentation is expected to be upgraded to link with the CGIAR System-wide Information Network on Genetic Resources (SINGER). No well documented inventory of forages and rangeland crops exists.

**Characterization evaluation**

At CIAT, 87% of forage species are identified by genus; a reference herbarium keeps specimens of about 70% of genera and species; morphological characterization has been carried out on 18% of conserved accessions, and 7% have been biochemically characterized. At ILRI, characterization based on nutritional, agronomic and morphological characteristics is limited to a set of priority species for livestock feed. These forages are being evaluated in a range of environments in sub-Saharan Africa by ILRI research programmes and by NARS through the African Feed Resources Network (AFRNET). At ICARDA, characterization has been done for some of the forage species. The number of evaluated accessions at ICARDA are: vetch

3,000, peas 1,200, *Medicago* 1,000 and *Trifolium* 200. All collections of temperate forages held at IGER in the United Kingdom pass through breeders' "phase I" evaluations for breeders' current objectives.

**Utilization**

Most of the germplasm held by CIAT, ICARDA and ILRI is distributed within the centres, but a growing number of NARS, especially in developing countries, receive accessions. Between 1992 and 1994, 39,460 samples were distributed by the CGIAR centres: CIAT (10,289), ICARDA (21,173) and ILRI (7,998). The degree and type of utilization vary. The main focus is on early varieties of forage legumes for testing in national programmes (ICARDA), on varieties with specific nutritional contents (the main demand by nutritionists at ILRI) and tropical grass varieties at CIAT where, since 1980, 13 species have been distributed as commercial cultivars in 12 tropical countries and China. Large areas in tropical and temperate zones are being re-sown to new varieties of grasses with a narrow genetic range. Forage varieties are being sown in areas adjacent to their wild relatives with which they can freely hybridize. It is possible that the natural gene pool may be partly replaced with genes from bred varieties.

## A2.3 STATE OF DIVERSITY OF MINOR CROPS

The state of diversity of selected minor and under-utilized crops is presented in the following Table A2.1.[35]

## Table A2.1 Selection of minor and underutilized species

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Noug, Niger *(Guizotia abyssinica)* | Edible oil, feed, illuminant. Used in soap and paint industries, silage and green manure | Ethiopia, East Africa | Cultivated in India, Ethiopia, Sudan, Uganda, United Republic of Tanzania, Malawi, Zimbabwe, Bangladesh | Small plots and in subsistence agriculture. Slight threat of genetic erosion at present. No known on-farm conservation programmes | About 1,700 accessions maintained in India and Ethiopia. Accessions are also maintained in other interested countries | Breeding work in Ethiopia and India. Selections were made from limited local collections. About 30 lines have been identified | Can grow in waterlogged areas and infertile soil; tolerant to high salinity and low soil oxygen level | Limited germplasm available, lack of technical information. Low yields might be due to environmental stress (growing in waterlogged soils) | Germplasm collection; strategy for conservation of landraces and selected types; genetic enhancement to improve the crop; wide scope for genetic improvement; promotion for wider use |
| Bambara groundnut (*Vigna subterranea)* | Seed (fresh and dry) mostly boiled, flour, porridge, feed, fodder | West Africa (Nigeria, Cameroon) and possibly Central Africa | Cultivated in West, East and Southern Africa. Introduced in Central America, Asia and Northern Australia | Small plots in traditional farming systems. Also an intercrop. No danger of genetic erosion. No known on-farm conservation programmes | 3,500 accessions maintained at IITA and 1,500 at ORSTOM. Also in South Africa, Zimbabwe, Mali, Zambia, Tanzania, Ghana, NBPGR, Botswana, Swaziland, Chad and Ethiopia | Some breeding work done for local selection | Can grow in dry areas; taste and flavour liked by consumers; indigenous crop, fits traditional farming systems | Lack of technical information, lack of interest by agriculturists and extension workers | Study of crop variability and selection of appropriate types for commercial production; processing and post-harvest study; germplasm is unexplored in areas of Africa |
| Lagos spinach, cockscomb, Puah grass, white soko, *(Celosia argentea)* | Leafy, vegetables, pot herbs, leaves for flavour and feeding animals, leaves for medicinal uses | Senegal and Cameroon | Cultivated in Africa, domesticated in Asia, wild forms are also available | Small plots, home gardens, subsistence use. No danger of genetic erosion. No known on-farm conservation programmes | Accessions maintained in Nigeria, Japan, South Africa, IITA and in countries of Southeast Asia. Descriptors developed | Breeding for varietal improvement and selection has been carried out | Technology is available to adopt the crop in farming systems | | Technology should be applied to adopt the crop in local farming systems. Study of the genetic relationship between *Celosia* and other related wild genera. Germplasm exchange for wider production |
| Hungry rice, fonio, fundi, acha, black foris, iburn *(Digitaria exilis)* | Erect, free tillering annual. Edible grain, flour can be used for porridge, beer, fodder, straw for handicrafts | Senegal to Cameroon (West Africa) | Cultivated in West Africa, (Nigeria, Togo, Benin, Sierra Leone) | Small-scale producers, subsistence crops; no threat to genetic erosion. No known on-farm conservation programmes | Underexplored genetic variability. Major collection maintained in ORSTOM (Montpellier); others in various interested institutes in West Africa (Nigeria, Senegal, Cameroon) and the United Kingdom | Little breeding work has been done. No major varieties are developed but there are local varieties | Can grow on poor soil and in dry areas. Short-duration crop | Little research has been done to interest large-scale producers | Collection of primary diversity from Africa; characterization and evaluation; strategy for conservation; development of improved cultivars |

> *(continued)* **Table A2.1 Selection of minor and underutilized species**

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Yams, white yam *(Dioscorea* spp.) | Root crop. Staple food in Central Africa, for the preparation of fufa, starch, yam peels for livestock feed | West and Central Africa | Peasant cultivators from West Africa to Southwest Africa, most tropical Africa; widely cultivated in the Caribbean | Cultivated for subsistence agriculture and staple food. No threat of genetic erosion. No known on-farm conservation programmes | Many countries in Africa have explored variability. 11,500 accessions maintained in the interested countries in Africa and the Caribbean | Limited breeding work to improve the crop | Good flavour, good cooking and storage properties; consumer preference in Africa | Labour intensive and high import requirements for greater yield. Lack of technical information. Disease problems | Germplasm collections from indigenous areas of Africa; post-harvest handling; product development for flour or flour-based products |
| Hyacinth bean, dolichos bean, lablab bean *(Lablab niger)* | Immature pods, young leaves, mature seeds | Tropical Asia and Africa | Cultivated in the Indian subcontinent, Southeast Asia, Egypt, Sudan, East and West Africa, the Caribbean, Central and South America and Australia | Small plots, home gardens, larger areas for forage in Australia. No serious danger of genetic erosion. No known on-farm conservation programmes | Countries in South and Southeast Asia maintain collections. Zimbabwe also maintains germplasm | Breeding work to meet local needs. Several varieties developed. Variability exists to improve crop | Multipurpose uses; suitable for dry areas; nutritious | Lack of information and exchange of germplasm. Lack of producer interest because of lack of extension | Systematic germplasm collection; characterization and evaluation; economic benefit assessment; market development |
| Jew's mallow, Bust Okora *(Corchorus olitorius)* | Leaves and young shoots; vegetable crop | Africa (but possibly also in India and Myanmar) | Cultivated in Asia, North Africa, tropical Africa, West Africa, South America and the Caribbean | Vegetable types often cultivated in small plots, kitchen gardens. Genetic erosion is now unlikely. No known on-farm conservation programmes | Bangladesh, India, China, Thailand, Kenya, Nigeria, Egypt, Sudan, Libyan Arab Jamahiriya, Zimbabwe maintain genetic resources in genebanks.Regional materialsmaintained at Jute Research Institute. 2,500 accessions maintained in Italy and Germany. Duplicates also maintained in Australia | Little attention to improve vegetable jute | Important as local vegetable; potential for further improvement; can improve carbohydrate-based diet | Lack of interest of agriculturists; lack of technical information and extension to expand growing areas | Sharing of germplasm between continents; assessment of genetic diversity; exploration of germplasm for vegetable type; conservation needed for vegetable types; further improvement of crop through germplasm enhancement |

### > *(continued)* Table A2.1 Selection of minor and underutilized species

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Breadfruit *(Artocarpus altilis)* | Carbohydrates, vegetables, starch leaves as fodder, latex. Staple food in the Pacific islands | Polynesia, Malaysia and Indonesia | Malaysia, Indonesia, Sri Lanka, India, Pacific Islands, Caribbean Islands. Cultivated widely in the Pacific Islands as staple food. Mostly found in home gardens in India and Sri Lanka | Cultivated in small orchards and home gardens, seedless type is in danger of genetic erosion | Germplasm maintained in Malaysia, Hawaii (173 accessions where isozyme analysis is carried out), and Australia, (number of accessions estimated at 400 or more) | Limited breeding work | Local varieties are available; already a staple food in many countries; root cuttings give 90% success for propagation; intercropping with other vegetables which require shade is possible; no major diseases and pests | The fruit has much more potential than realized at present by agriculturists; short shelf-life for vegetables | Germplasm collection and conservation especially for seedless types that are in danger of erosion. Selection of superior types for multi-uses through evaluation. Post-harvest handling and storage; product development |
| *Amaranthus,* African spinach, Indian spinach, green leaf *(Amaranthus* spp. vegetable and grain types) | Edible leaves, grains make soups, custards, stews, desserts, drinks, bread, cakes, popcorn, chocolate powder, syrups and sweets | Ecuador, Peru, Bolivia, Argentina, (Andean region of South America) | Cultivated forms grown in India, Malaysia, Indonesia, Myanmar, the Philippines, South and East Asia, Far East, South Pacific, tropical Africa, the Caribbean, Central and South America | Unlikely that the usual varieties will be abandoned and that serious genetic erosion will occur in the species. A large number of local strains and selections exist | Many accessions (over 5,000) in genebanks, mostly in United States and India. Other institutes and universities have working collections | Breeding work has been carried out in different regions of the world. Requires further work to improve the production of leaf and grain types | Excellent nutritional quality; tolerance to aluminium toxicity; established cultivation; low cost of the unprocessed grain; accepted by consumers | Little attention has been given to certain tropical regions e.g. Africa. Lack of attention by agriculturists/ extension workers | Completing collection evaluation, characterization documentation; breeding varieties with less dehiscence, greater uniformity of ripening, resistance to drought, frosts and soil alkalinity, tolerance to the main pests and diseases |
| Rice bean *(Phaseolus calcaratus)* | Young and dry seeds, pods, leaves, sprouts | India, South China | Cultivated in Indian subcontinent, tropical Asia and Africa, South Pacific, Southeast Asia, West Indies | Small plots, home gardens, large areas in hill farming. No threat of genetic erosion | Maintained in genebanks by AVRDC, IITA, United States, India and other countries interested in this crop | Limited breeding programmes to improve this crop | Multipurpose nutrition crops, short duration, low susceptibility to pests and disease | Lack of interest by agriculturists/ extension officers, lack of technical information, lack of availability of wider germplasm | Germplasm collection; characterization and evaluation; systematic breeding programmes for local utilization; post-harvest study for young bean and for packaging |

## > *(continued)* Table A2.1 Selection of minor and underutilized species

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Jackfruit, Jak *(Artocarpus heterophyllus)* | Fresh fruit, young fruit and seed as vegetables and preserves, dried pulps as food, resin from bark used as sealer, timber and leaves as fodder | India, wild types found in Western Ghat, India | Indian subcontinent, Southeast Asia, introduced to Africa, the Caribbean. Commercial cultivation is limited, commercial orchards established in few countries in South and Southeast Asia, particularly in Malaysia, Myanmar and Brazil | Cultivated in most countries in Asia, but mostly in home gardens. No danger of genetic erosion; underexplored genetic variability; no systematic conservation plan | About 300 accessions in India Bangladesh, Sri Lanka, Malaysia, Thailand and Viet Nam | Limited breeding work. There are some local varieties in most of the growing countries (only two distinct types). Appropriate breeding programmes are needed | Commercially viable crop; excellent candidate for agroforestry; multipurpose uses makes the tree popular | Marketing is poor; lack of post-harvest knowledge; absence of standardized propagation methods; pests and diseases (e.g. shoot-borer caterpillar, die-back disease) | Collection of germplasm, characterization and evaluation; selection for superior types for fruit and timber; *in situ* conservation, standardization of propagation; management of post-harvest technology; establishment of marketing channels |
| Durian *(Durio zibethinus)* | Pulp eaten fresh. Cooked as vegetable or in soups, processed into various products, seeds roasted or boiled, confectionery, frozen and dried pulp | Malaysia, Indonesia, Thailand and the Philippines | Cultivated in tropical Asia, introduced to many countries of the tropics, mainly cultivated in Malaysia, Indonesia, Thailand, Sri Lanka and the Philippines | Serious genetic erosion is not considered yet, as it is unlikely that usual varieties will be abandoned | Genetic variability has been studied. 1,160 accessions maintained in Malaysia and Thailand and also some maintained in Sri Lanka | Breeding work in Southeast Asia for crop improvement | Economic crop in many countries. Multipurpose uses for local markets | Root rot, uneven fruit ripening, strong aroma | Cultivar selection is required for wider acceptability and utilization of fruits, stock-scion interaction studies to develop cultivars with desirable traits |
| Cocoyam, taro *(Colocasia esculenta)* | Starch, edible, boiled, roasted, baked, vegetable, food and beverage industries, pasta products, young leaves as spinach | Southeast Asia, Upper Myanmar | Cultivated in China, Japan, West Indies, South Pacific and south United States, the Caribbean, introduced to Europe, Africa, Egypt, tropical Asia and the Pacific | Danger of serious genetic erosion | 5,966 accessions stored worldwide. Largest collections in Malaysia, Papua New Guinea, India and United States | On-going breeding programmes for a few cultivated varieties developed for specific use | Adapted to high temperature; poor soil | Lack of interest by agriculturists/ extension officers, lack of exchange of germplasm to exploit the genetic potential of the crop. Infested by pests and diseases | Limited information on storage. *In vitro* conservation strategy needed; germplasm exchange; virus cleaning for safe germplasm exchange; multilocation evaluation |

**> *(continued)* Table A2.1 Selection of minor and underutilized species**

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Rocket *(Eruca sativa)* | Fresh and frozen leaves, seed for oil, plastic, lubricant, insecticide | Mediterranean region | Cultivated in a limited area in the Mediterranean region. It is in semi-domestication in Italy and Israel | At present mostly grown in small plots.Trials for adoption are in progress. Threat of genetic erosion is high.Wild relatives considered important but none collected yet | Conservation measures in genebank (Italy) but also in some other interested countries | Limited breeding or improvement measures | Potential for industrial and food crops | Lack of information on technical aspects including post-harvest quality and susceptibility to diseases | Germplasm collection from the Mediterranean region; *ex situ* conservation; characterization and evaluation; selection of good types |
| Buckwheat *(Fagopyrum esculentum)* | Erect, annual, flour, pancakes, porridge, feed, honey, dye and rutin from leaves and flowers used for medicine | Central Asia | Cultivated in Far East, in hilly areas of the Indian subcontinent and Southeast Asia, Russian Federation, Poland and Eastern Europe. Introduced to northern and southern Europe, North America | Small-scale production in hill farming systems in India, Nepal. No threat of genetic erosion yet. No specific on-farm conservation programmes | Limited exploration of genetic variability, mostly in Eastern Europe and partly in China. Accessions (33,100) maintained in Poland, Japan, India, VIR, Canada and other interested institutes | Limited breeding work in Poland, the former republics of Yugoslavia, Russia and now in Japan and China | Well-adapted to poor soils, short growing season, can grow at high elevations | Lack of technical information, lack of interest by agriculturists/ extension workers | Collection of landraces; strategy for conservation; product development; genetic enhancement |
| Carob, John's bread *(Ceratonia siliqua)* | Fruit and seeds for food, forage, industrial grain, cosmetic and textile industries, insecticides, erosion control, hard and heavy wood for local furniture | Mediterranean basin | Cultivated in Cyprus, Israel, Lebanon, Algeria, North Africa, Southern Africa, Australia, Indian subcontinent, Near East, southern Europe (Greece, Italy, Spain, Portugal) | Sporadically grown in southern Europe. No specific on-farm conservation programmes | Genetic variability underexplored in the indigenous centre; being explored in Spain; limited levels of germplasm maintained in interested countries | Limited breeding work carried out. A few varieties selected in southern Europe | Can grow on steep slopes, semi-arid areas, no irrigation required, multipurpose use. Used for agroforestry | Slow growth, alternate bearing | Germplasm collection; strategy for conservation; characterization and evaluation; selection of good clones; synchronized pollen production |
| White lupins, yellow lupins, tarwi (*Lupinus* spp. *L .albus, L. luteus* and *L. mutabilis)* | Annuals. High-protein food, forage and oil crops. Insecticidal usage (repellent) and in other industries | Mediterranean and South America (*L. mutabilis*) | Cultivated in Europe, North Africa, introduced in Russian Federation, Australia. *L. mutabilis* is grownin traditional farming systems in South America | Large forage crop in Europe and Australia (*L. angustifolius*) and a subsistence crop in the Andes. No real threat of genetic erosion | Some landraces are explored for variability and accessions are maintained in interested countries. 28,500 accessions worldwide in Germany, Spain, Poland, United Kingdom | Breeding for protein and forage lupins has been in progress. Non-alkaloid lupin selection was made for *L. albus* and *L. mutabilis*. No systematic breeding work for multipurpose *L. mutabilis*. | Low alkaloid types, compact inflorescence *of L. mutabilis* makes the crop suitable for large-scale cultivation because of ease of harvesting | Lack of plant breeding ideotypes | Germplasm collections from unexplored areas; adaptive research for *L. mutabilis* and in wider areas for *L. albus*. Strategy for conservation; product development |

> *(continued)* **Table A2.1 Selection of minor and underutilized species**

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Walnut *(Juglans regia)* | Tree, nuts used fresh, roasted, salted, confectionery, pastries, flavouring, leaves for insect repellent, fleshy part produces dye, oil used in paints, soap-making, leaves for fodder, hard wood for furniture | Central Asia | Cultivated in temperate zones of the old and new worlds. Adapted to slopes, introduced in Chile and then in North America | Small and large orchards, commercial production, major cultivation in United States but tremendous potential in other temperate regions. No threat of genetic erosion. No known on-farm conservation programmes | Mostly explored in United States for genetic variability but other areas unexplored. Germplasm maintained by interested institutes | Breeding work in United States but limited work in other areas; potential work in West Asia | Agroforestry, limits soil erosion, good produce and expanding market | Lack of technical information in new areas to exploit its potential. Takes long time to bear produce | Adaptive research in new areas, e.g. Pakistan, Afghanistan, Peru; germplasm collection; conservation strategy; promotion for wider cultivation in lands where no other crops suited |
| Meadowfoam *(Limnanthes alba)* | Oleochemical products, cosmetics industry and in special technical applications | North America | Cultivated mostly in North America. Recent introduction to Europe where adaptive trials have started | Small plot trials for adaptation in wider agroclimatic region. Large areas cultivated in California, Oregon and Maryland. No known on-farm conservation programmes | Unexplored genetic variability; germplasm maintained by USDA and interested institutes/industries in United States and Europe | Limited breeding work | Superior seed retention and can grow as a winter crop; industrial uses | Lack of technical information, limited access to germplasm | Germplasm collection, characterization and evaluation; genetic enhancement to improve the crop |
| Safflower *(Carthamus tinctorius)* | Vegetable oil, dye, purgative, foliage as medicine, cosmetics, industry, fodder and feed | Far East, Southern Europe, South Asia, Africa, West Asia (primary centre of diversity) | Cultivated in Asia, Africa, Mediterranean basin, North America, introduced to Central and South America | Smallholder peasant farmers, for dye and oil; large-scale cultivation in a few countries; no known conservation programmes. No threat yet of genetic erosion | Variability has been explored and a few varieties selected. Accessions stored in United States, Israel, Russian Federation, India | Breeding work is in progress in a few countries (India, Israel, North America, etc.). Further work needed to select varieties for higher yield and oil productivity | Can grow in drier areas, large genetic variability to improve crop for oil, dye and other products | Susceptibility to disease and pests, early maturing for European growers, thickness of hull | Selection of suitable types for Europe; germplasm collection for unexplored areas; maintenance of pure strains of indigenous varieties; increased utilization |
| Chayote *(Sechium edule)* | Human consumption (fruit), fodder, baskets and hats (stems), medicinal purposes | Mexico and Guatemala | Mesoamerica, Antilles, South America, Europe, Africa, Asia, Australia, United States | Unlikely that the usual varieties will be abandoned and that serious genetic erosion will occur in the species. No known conservation programmes | Recalcitrant seed: between 1988 and 1990 many collections were lost. Smaller collections remain in Mexico, Nicaragua and Brazil | None | Commercial export production established (Costa Rica, Guatemala, Mexico, Dominican Republic) | | Establishment of permanent genebanks; selection of varieties; evaluation and use of wild relatives for genetic improvement; disease studies |

> *(continued)* **Table A2.1 Selection of minor and underutilized species**

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Sapote *(Pouteria sapota)* | Edible fruit, jams, icecreams, sauces, confectionery, linen starch, medicinal | South America | Central America, South America, Antilles, Nicaragua, Puerto Rico, Guatemala, United States, | Much unexplored genetic variability in the tropical forest areas | Collections exist | Selection trials in Cuba | Commercial production established (Nicaragua) | Current production cannot meet demand | Selection of superior genotypes; evaluation; production and processing for local consumption and for export; marketing |
| Spanish plum, red mombin, golden apple *(Spondias purpurea)* | Edible fruit, soft drinks, preserves syrups | From Sinaloa and Jalisco in Mexico to Colombia | Mesoamerica from Mexico to Colombia. South America, Southeast Asia and also in subtropical areas of United States | Most production from isolated trees or hedges, very little from plantations. Absence of seed formation completely limits natural distribution. Crossing barriers limit utility of wild relatives | Not reported | Not reported | Consumption, tolerant to drought and poor soil, vegetative propagation | Lack of attention by producers, technical experts and agricultural extension workers; fruit flies cause serious damage | Establishment of genebank; characterization and evaluation of clonal variation between existing varieties, especially for resistance to fruit flies. Distribution of germplasm to growers |
| Tomatillo, husk tomato *(Physalis philadel-phica)* | Sauces and purees prepared with its fruit; medicinal properties | Mesoamerica, from southern Baja California to Guatemala, domesticated in Mexico | Cultivated and collected from the wild in Mexico, Guatemala, United States, Europe, Spain | The species of *Physalis* in Mexico and Guatemala are not in any immediate danger of genetic erosion | Genebank collections in Mexico and Guatemala | Two Mexican varieties produced by INIFAP, which are rarely used | In Mexico agro-industrial production and processing (600 tonnes per year, 80% exported) at early stages of domestication | | Collection of both cultivated and wild plants to consolidate genebanks; genetic improvement work in Mexico and Guatemala |
| Canihua *(Chenopodium pallidicaule)* | Grain for human consumption; flour is used in porridges, cold or hot drinks, bread biscuits; also has medicinal uses | Centre of diversity is limited to the Peruvian and Bolivian high plateaus | Bolivia, Peru | Selected varieties have not yet been introduced on a large scale. There is no danger of genetic erosion | Short-term collections in Peru and Bolivia | The alkaloid-free variety, Inti, bred in Chile by von Baer, is currently available | Very cold-resistant (10° to 28°C), saline tolerant, high-protein (1,519%) and sulphur containing amino acids content. Low in saponins, day-neutral with good adaptability | | Collection to complete *ex situ* collections; characterization and evaluation; improvement of ripening uniformity, dehiscence and grain size traits; genetic and agronomic evaluation of its potential |

## > *(continued)* Table A2.1 Selection of minor and underutilized species

| Species | Form and use | Centre of diversity | Cultivation/use | On-farm status | *Ex situ* status | Breeding programme | Strength | Weakness | Priorities |
|---|---|---|---|---|---|---|---|---|---|
| Oca *(Oxalis tuberosa)* | Edible, flour | Andes from Colombia to Bolivia | Peru, Bolivia, Venezuela, northern Argentina and Chile, Mexico, New Zealand | | Field and *in vitro* collections in Peru, a field collection in Ecuador | | High response to agricultural work with yields comparable to potato. Alternative source of flour to wheat | | |
| Multipurpose trees (MPTs) | Of the 50,000 species of woody plants in existence, 2,500 so far have been described suitable for agroforestry as multipurpose trees or bushes | Varies from species to species | Varies from species to species | Not well reported | At ICRAF the following species are stored: *Sesbania* spp., *Irvingia* spp., *Grevillea robusta, Markhamia utea, Prosopsis africana, Inga* spp., *Bactris gasipaes.* Collections of MPTs also in Kenya, ILRI, IITA | Very little breeding, until now accessions only used for on-site or on-farm trials | MPTs show more population differentiation than agricultural crops. Their co-adapted gene complexes deserve appropriate conservation and utilization | Size and perenniality of MPTs have repercussions on evaluation and regeneration; lengthy testing. Outbreeding and dioecy is more prevalent in MPTs than in agricultural crops which complicates sampling and replication | Exchange of germplasm; intensification of research |

## Annex 2 endnotes

[1] Sugar cane is reviewed in this annex. However, in many temperate countries, a large proportion of sugar is provided by sugar beet.

[2] FAO (1991) *Food Balance Sheets; 1984-1986 average*. FAO, Rome, 384 pp.

[3] All of the 1995 production and cultivated area data were obtained from the WAICENT Agricultural Statistics System available from the FAO Statistics Division. The production tonnages and cultivated areas have been adjusted to the nearest million tonnes/hectares.

[4] Op. cit., endnote 2.

[5] System wide Programme on Genetic Resources (1996) *Report of the Internally Commissioned External Review of the CGIAR Genebank Operations*. CGIAR, Washington, DC.

[6] All of the mandate crops of the CGIAR centres are comprehensively reviewed in CGIAR (1996) *Biodiversity in trust*. Cambridge University Press, Cambridge, UK.

[7] Where information has been provided by Country Reports, it is reported. However, as the information provided in Country Reports varies considerably from country to country, the absence of information does not necessarily signify a negative response. For instance, de facto on-farm conservation for all of these crops exists wherever locally adapted landraces are grown by farmers, yet this may not be reported in all Country Reports.

[8] Other acronyms are listed in Appendix 2.

[9] The following crop experts provided information: wheat (Rowe R, CIMMYT), rice (Virmani S, IRRI; Mackill DJ, USDA-ARS, University of California, Davis, USA ), maize (Rowe R, CIMMYT; Taba S, CIMMYT), potato and sweet potato (Huaman Z, CIP), soybean (Nelson R, USDA-ARS, USA; Carter T, USDA-ARS, North Carolina State University, USA); sugar cane (Burnquist W, Copersucar Technology Centre, Piracicaba, Brazil; Irvine JE, Texas A&M University, Texas, USA); temperate forages (Sackville-Hamilton R, IGER, Wales, UK).

[10] This information was supplied through a FAO statistical information system (Agrostat).

[11] Plucknett DL, Nigel JHS, Williams JT and Anishetty NM (1987) *Gene banks and the world's food*. Princeton University Press, New Jersey, USA, 111 pp.

[12] The y-axis of the crop yield graphs extends to approximately three times the yield of the crop in 1961. This range was based on the threefold yield increases achieved with rice, a crop that has received much breeding attention from the public sector.

[13] Many of the others were selected from: FAO (1994) *Cultivos marginados otra perspectiva de 1492*. FAO; Rome, 339 pp. Other information was provided by IPGRI.

[14] Also shown as *Aegilops squarrosa*.

[15] Rejesus R, Van Ginkel M and Smale M (forthcoming). Wheat breeders perspectives on genetic diversity and germplasm use: findings from an international survey. *Plant Varieties and Seeds*, 9:129-147.

[16] National Research Council (NRC) (1993) . *Agricultural crop issues and policies. managing global genetic resources.* Committee on Managing Global Genetic Resources: Agricultural Imperatives. National Academy Press, Washington, DC, 449 pp.

[17] IPGRI (1995) IRRI redesigns rice plant to yield more grains. *Plant Genetic Resources Newsletter,* 102:44-45.

[18] Goodman MM (1990) Genetic and germplasm stocks worth conserving. *Journal of Heredity,* 81:11-16.

[19] CIRAD (1995) *Plants: yesterday, today and tomorrow*, p. 71-73. CIRAD; Paris.

[20] Maunder AB (1992) Identification of useful germplasm for practical plant breeding programs. In Stalker HT and Murphy JP (eds.) *Plant breeding in the 1990s.* p. 147-169. CAB International; London

[21] Miller FR and Kebebe Y (eds.) (1984) *Genetic contribution to yield gains in sorghum, 1950 to 1980*, p. 1-14 Genetic contributions to yield gains of five major crop plants. CSSA Spec. Publ. 7. CSSA and ASA, Madison, Wisconsin, USA.

[22] There is a need to establish field genebanks in suitable areas for germplasm that is not suited to the environmental conditions at CIAT headquarters.

[23] Persley GJ (1990) *Beyond Mendel's garden: biotechnology in the service of world agriculture*, p. 131-132. World Bank/ISNAR/ACIAR/AIDAB Biotechnology Study, CAB International, London.

[24] Asiedu R, Hahn SK, Bai KV and Dixon AGO (1989) *Introgression of genes from wild relatives into cassava.* Paper presented at the fourth Triennial Symposium of the International Society for Tropical Root Crops - Africa Branch, 4-8 December 1989, Kinshasa, Zaire.

[25] Simmonds NW (1993) Introgression and incorporation. Strategies for the use of crop genetic resources. *Biological Review*, 68:539-562.

[26] The available FAO data on dry beans cover all species of *Phaseolus* and in a few countries, such as India, also *Vigna* species. In certain countries where a considerable amount of dry beans is grown mixed with other crops (e.g. maize), area data may be subject to overestimation and yields per hectare data to underestimation.

[27] The W-6 collection is a medium-term "active" collection, which contains duplicates of material in NSSL.

[28] McClean PE, Myers JR and Hammond JJ (1993) Coefficient of parentage and cluster analysis of North American dry bean cultivars. *Crop Science,* 33:190-197.

[29] NRC (1972) *Genetic vulnerability of major crops.* Committee on Genetic Vulnerability of Major Crops. National Academy of Sciences, Washington, DC, USA, 307 pp.

[30] SOY-N is an active collection containing duplicates of materials found in NSSL.

[31] Communication from the Chinese Academy of Sciences (1995).

[32] Gizlice Z, Carter TE Jr and Burton JW (1993) Genetic diversity in North American soybean: I. Multivariate analysis of founding stock and relation to coefficient of parentage. *Crop Science,* 33:614-620.

[33] This includes sugar derived from sugar beet.

34 Total biomass yield may not be an ideal indicator of breeding success for sugar cane, as most breeding is for increased sugar content.

35 Based largely upon information provided by: the International Centre for Underutilized Crops, UK; FAO (1994) *Cultivos marginados otra perspectiva de 1492*. FAO, Rome, 339 pp. Also based upon information provided by IPGRI.

# APPENDIX 1
# Status by Country of National Legislation, Programmes and Activities for PGRFA

The information provided is derived from Country Reports and the World Information and Early Warning System on Plant Genetic Resources (WIEWS).

## Legend

1. Participation in the preparatory process for the International Technical Conference:

   ◯ focal point,
   ◑ country report,
   ◐ subregional meeting,
   ● country report and subregional meeting.

2. Countries and territories are listed according to the subregions used during the preparatory process for the International Technical Conference. In some cases country names have been abbreviated for reasons of space.

3. Commission on Genetic Resources for Food and Agriculture:

   ◯ non-member,
   ● member.

4. International Undertaking on Plant Genetic Resources:

   ◯ not adhered,
   ● adhered.

5. Convention on Biological Diversity:

   ◯ signed,
   ● ratified.

6. Quarantine policy:

   ◯ national regulations,
   ◑ in preparation,
   ● member International Plant Protection Convention.

7. 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.

8. Seed quality control:

◑ seed quality control,

◐ seed certification.

9. 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.

10. Conservation *ex situ* (LT = long-term; MT = medium-term; ST = short-term):

○ no genebank,

◑ ST/MT storage,

◐ LT storage or MT/LT,

● LT managed.

11. Crop improvement programme status:

○ no programme,

◑ basic,

◐ developed,

● advanced.

12. Subregional Networks: ECP (European Cooperative Programme on Crop Genetic Resources Networks), WANA (The West Asia and North Africa 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 of PGR), PRO (PGR subregional network for the countries of the southern cone), TRO (Amazonian Network of PGR), REM (Central American Network of PGR), CCM (Caribbean Committee on Management of PGR), ANZNPGRC (Australian and New Zealand Network of PGR Centres).

13. 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 the result of differences in the number of institutions included in a country's listing.

## Status by country

| Preparatory process[1] | Country[2] | Commission on GRFA[3] | International Undertaking[4] | Convention on Biodiversity[5] | Legislation: Quarantine[6] | Legislation: Plant breeders' rights[7] | Legislation: Seed quality control[8] | National capacity: National programmes[9] | National capacity: Conservation *ex situ*[10] | National capacity: Crop improvement[11] | Subregional network[12] | Genebank accessions[13] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Europe** | | | | | | | | | | | |
| | **Western Europe** | | | | | | | | | | | |
| | Andorra | | | | | | | | | | | |
| ● | Austria | ● | ● | ● | ● | ◐ | ◐ | ◐ | ● | ● | ECP | 7,891 |
| ● | Belgium | ● | ● | ○ | ● | ● | ◐ | | ● | ● | ECP | 9,750 |
| ● | Denmark | ● | ● | ● | ● | ● | ◐ | ● | | ● | ECP | 3,660 |
| ● | Finland | ● | ● | ● | ● | ◐ | ◐ | ● | | ● | ECP | 2,323 |
| ● | France | ● | ● | ● | ● | ● | ◐ | ◐ | ● | ● | ECP | 249,389 |
| ● | Germany | ● | ● | ● | ● | ● | ◐ | ◐ | ● | ● | ECP | 200,000 |
| ● | Greece | ● | ● | ● | ● | | ◐ | ● | ◐ | ● | ECP | 17,556 |
| ● | 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 |
| | **Eastern Europe** | | | | | | | | | | | |
| ◑ | 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 |
| | Former Yugoslav Republic of Macedonia | ○ | ○ | | | | ◑ | | | | | |
| ● | Moldova, Republic | ○ | ○ | ● | ○ | | ◐ | ◐ | ◑ | ◐ | | 6,000 |
| ● | Poland | ● | ● | ● | ○ | ◑ | ◐ | ● | ● | ● | ECP | 91,802 |

> *(continued)* **Status by country**

| Preparatory process[1] | Country[2] | Commission on GRFA[3] | International Undertaking[4] | Convention on Biodiversity[5] | Legislation: Quarantine[6] | Legislation: Plant breeders' rights[7] | Legislation: Seed quality control[8] | National capacity: National programmes[9] | National capacity: Conservation *ex situ*[10] | National capacity: Crop improvement[11] | Subregional network[12] | Genebank accessions[13] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Eastern Europe** | | | | | | | | | | | |
| ● | Romania | ● | ● | ● | ● | ○ | ◐ | ● | ● | ● | ECP | 93,000 |
| ● | Russian Federation | ○ | ● | ● | ● | ○ | ◑ | | ◑ | ● | ECP | 333,000 |
| ● | Slovakia | ● | ○ | ● | ○ | ◐ | ◐ | ● | ◐ | ◐ | ECP | 14,547 |
| ◐ | Slovenia | ○ | ○ | ○ | | | | | | | | 2,676 |
| ● | Ukraine | ○ | ○ | ● | ○ | ◐ | ◐ | ● | ◐ | ◐ | | 136,400 |
| ◑ | Yugoslavia | ● | ● | ○ | ● | | ◐ | | ◑ | ◐ | ECP | 38,000 |
| | **Near East** | | | | | | | | | | | |
| | **South/East Mediterranean** | | | | | | | | | | | |
| | Algeria | ● | ● | ● | ● | | | | | | WANA | 985 |
| ● | Cyprus | ● | ● | ○ | ○ | | ◐ | | ◐ | ◐ | ECP, WANA | 12,313 |
| ● | Egypt | ● | ● | ● | ● | | ◐ | ○ | ◐ | ◐ | WANA | 8,914 |
| ● | Israel | ● | ● | ● | ● | ● | ◐ | ◐ | ● | ● | ECP | 56,123 |
| ● | Jordan | ● | ○ | ● | ● | | ◐ | ◑ | ◑ | ◐ | WANA | 3,588 |
| ● | Lebanon | ● | ● | ● | ● | | ◐ | | ◑ | ◐ | WANA | |
| ◑ | Libyan Arab Jama. | ● | ● | | ● | | | | ◑ | ◐ | WANA | 2,313 |
| | Malta | ● | ○ | | ● | | | | ○ | ○ | | |
| ● | Morocco | ● | ● | ● | ● | | ◐ | ◑ | ◐ | ◐ | WANA | 20,470 |
| ● | Palestine | ○ | ○ | | | | | | | | | |
| ● | Syrian Arab Rep. | ● | ● | | ○ | | ◐ | ● | ◐ | ◐ | WANA | 8,750 |
| ● | Tunisia | ● | ● | ● | ● | | ◐ | ◑ | ◑ | ◐ | WANA | 1,768 |
| | **West Asia** | | | | | | | | | | | |
| | Afghanistan | ● | ○ | ○ | | | ◑ | | | | | 2,965 |
| | Bahrain | ○ | ● | ○ | ● | | | | | | | |
| ● | Iran, Islamic Republic | ● | ● | ○ | ● | | ◐ | ● | ● | ◐ | WANA | 40,000 |
| ● | Iraq | ● | ● | | ● | | ◐ | ● | ◐ | ◐ | WANA | 6,400 |
| | Kuwait | ○ | ● | ○ | | | | | | | | |
| ◑ | Oman | ○ | ● | ● | ● | | | | ◑ | ◑ | WANA | 238 |
| ● | Pakistan | ● | ○ | ● | ● | | ◐ | ● | ● | ◐ | WANA | 19,208 |
| ◑ | Qatar | ○ | ○ | ○ | | | | ◑ | ○ | ◑ | | |
| ◑ | Saudi Arabia | ○ | ○ | | | | ◑ | ○ | ○ | ◐ | | |
| ● | Turkey | ● | ● | ○ | ● | | ◐ | ◐ | ● | ● | ECP, WANA | 40,000 |
| | United Arab Emirates | ○ | ○ | ○ | | | | | | | | |
| ● | Yemen | ● | ● | ○ | ● | | ◐ | ◐ | ◑ | ◑ | WANA | 4,229 |
| | **Central Asia** | | | | | | | | | | | |
| ● | Azerbaijan | ○ | ○ | ○ | ○ | | | ◑ | ◑ | ◐ | | 25,000 |
| ● | Kazakhstan | ○ | ○ | ● | ○ | | | ◑ | ◑ | ◐ | | 33,000 |
| | Kyrgyz, Republic | ○ | ○ | | | | | | | | | |
| | Tajikistan | ○ | ○ | | | | | | | | | |
| ● | Turkmenistan | ○ | ○ | | ○ | | | | ◑ | ◐ | | 4,832 |
| ● | Uzbekistan | ○ | ○ | ● | ○ | | ◐ | ◑ | ◑ | ◐ | | 50,000 |

> (continued) **Status by country**

| Preparatory process | Country | Commission on GRFA | International Undertaking | Convention on Biodiversity | Legislation: Quarantine | Legislation: plant breeders' rights | Legislation: Seed quality control | National capacity: National programmes | National capacity: Conservation *ex situ* | National capacity: Crop improvement | Subregional network | Genebank accessions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Africa, South of Sahara** | | | | | | | | | | | |
| | **West Africa** | | | | | | | | | | | |
| ● | Benin | ● | ● | ● | ○ | | ◐ | | ◑ | ◐ | | 2,453 |
| ● | Burkina Faso | ● | ● | ● | ● | | ◑ | | ◐ | ◐ | | 850 |
| | Cape Verde | ● | ● | ● | ● | | | | ◑ | ◑ | | |
| ◑ | Chad | ● | ● | ● | | | ◑ | | | | | 69 |
| ● | Côte 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 |
| | **Central Africa** | | | | | | | | | | | |
| ● | Cameroon | ● | ● | ● | ○ | | ◑ | ◐ | ◐ | ◐ | | 2,329 |
| ● | Central African Republic | ● | ● | ● | | | | | ◑ | ○ | | |
| ● | Congo | ● | ● | ○ | ○ | | | ◑ | ◑ | ◐ | | 1,755 |
| ● | Dem. Rep. Congo | ● | ○ | ● | ○ | | ◑ | ◐ | ◑ | ◐ | | 18,830 |
| ● | Equatorial Guinea | ● | ● | ● | ● | | | | ○ | ○ | | |
| ● | Gabon | ● | ● | ○ | ○ | | | ◑ | ◑ | ○ | | 91 |
| | Sao Tome and Principe | ○ | ○ | ○ | | | | | | | | |
| | **Southern Africa** | | | | | | | | | | | |
| ● | Angola | ● | ● | ○ | | | | ○ | ◐ | ◑ | SPG | 599 |
| ● | Botswana | ● | ○ | ● | ○ | | ◐ | ● | ◐ | ◐ | SPG | 3,390 |
| ● | Lesotho | ● | ○ | ● | | | ◑ | ● | ○ | ○ | SPG | 293 |
| ● | Malawi | ● | ● | ● | ● | | ◐ | ● | ◐ | ◐ | SPG | 11,421 |
| ● | Mozambique | ● | ● | ● | ○ | | ◐ | ● | ◑ | ◐ | SPG | 1,872 |
| ● | Namibia | ○ | ○ | ○ | | | ◑ | ◐ | ◐ | ◑ | SPG | 1,600 |
| ● | South Africa | ● | ● | ● | ● | ◑ | ◐ | ○ | ◐ | ● | SPG | 48,918 |
| ● | Swaziland | ○ | ○ | ● | ○ | | ◐ | ● | ◑ | ◑ | SPG | 325 |
| ● | Tanzania, United Rep. | ● | ● | ○ | ○ | | ◐ | ● | ◐ | ◐ | SPG | 2,510 |
| ● | Zambia | ● | ● | ● | ● | | ◐ | ◑ | ◑ | ◐ | SPG | 5,901 |
| ● | Zimbabwe | ● | ● | ● | ○ | ○ | ◐ | ◑ | ◐ | ◐ | SPG | 45,698 |

> *(continued)* **Status by country**

| Preparatory process[1] | Country[2] | Commission on GRFA[3] | International Undertaking[4] | Convention on Biodiversity[5] | Legislation: Quarantine[6] | Legislation: Plant breeders' rights[7] | Legislation: Seed quality control[8] | National capacity: National programmes[9] | National capacity: Conservation *ex situ*[10] | National capacity: Crop improvement[11] | Subregional network[12] | Genebank accessions[13] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **East Africa** | | | | | | | | | | | |
| ◐ | Burundi | ● | ○ | ○ | | | ◑ | | | | | |
| | Djibouti | ○ | ○ | ● | | | | | | | | |
| ● | Eritrea | ● | ○ | | | | | ○ | ◑ | ◑ | | 1,087 |
| ● | Ethiopia | ● | ● | ● | ● | | ◐ | ● | ● | ◐ | | 54,000 |
| ● | Kenya | ● | ● | ● | ● | ○ | ◐ | ◐ | ● | ● | | 50,037 |
| ◑ | Rwanda | ● | ● | ○ | | | ◑ | ○ | ◑ | ○ | | 6,168 |
| | Somalia | ○ | ○ | | | | | | | | | 94 |
| ● | Sudan | ● | ● | ● | ● | | | ◑ | ◐ | ◐ | | 5,178 |
| ● | Uganda | ● | ○ | ● | ○ | | ◐ | ◑ | ◑ | ◐ | | 11,483 |
| | **Indian Ocean Islands** | | | | | | | | | | | |
| | Comoros | ○ | ○ | ● | | | | | | | | |
| ● | Madagascar | ● | ● | ○ | ○ | | ◑ | | ◑ | ◐ | | 15,000 |
| ● | Mauritius | ● | ● | ● | ● | | ◑ | | ◐ | ◐ | SPG | 3,310 |
| ● | Seychelles | ○ | ○ | ● | ○ | | | | ◑ | ◑ | | 369 |
| | **Asia and Pacific** | | | | | | | | | | | |
| | **South Asia** | | | | | | | | | | | |
| ● | Bangladesh | ● | ● | ● | ● | | ◐ | | ◐ | ◐ | SAS | 45,309 |
| ◑ | Bhutan | ○ | ○ | ● | ● | | | | | | SAS | 40 |
| ● | India | ● | ● | ● | ● | | ◐ | ● | ● | ● | SAS | 342,108 |
| ● | Maldives | ● | ○ | ● | | | | | ○ | ○ | SAS | |
| ● | Nepal | ● | ● | ● | ○ | | | | ◑ | ◐ | SAS | 8,383 |
| ● | Sri Lanka | ● | ● | ● | ● | | ◐ | | ◐ | ◐ | SAS | 11,781 |
| | **Southeast Asia** | | | | | | | | | | | |
| | Brunei | ○ | ○ | | | | ◑ | | | | REC | |
| ● | Cambodia | ○ | ○ | ● | ● | | | | | | REC | 2,155 |
| ● | Indonesia | ● | ○ | ● | ● | | ◑ | ◑ | ◐ | ◐ | REC | 26,828 |
| | Laos | ○ | ○ | | ● | | ◑ | | | | REC | |
| ● | Malaysia | ● | ○ | ● | ● | | ◐ | ◑ | ◐ | ◐ | REC | 38,255 |
| ● | Myanmar | ● | ○ | ● | ○ | | | | ◐ | ◑ | REC | 8,000 |
| ● | Philippines | ● | ● | ● | ● | | ◐ | ◑ | ● | ● | REC | 59,399 |
| | Singapore | ○ | ○ | | | | | | | | REC | |
| ● | Thailand | ● | ○ | ○ | ● | | ◐ | ● | ◐ | ◐ | REC | 32,404 |
| ● | Viet Nam | ● | ○ | ● | ○ | | ◐ | ● | ◐ | ◐ | REC | 21,493 |
| | **East Asia** | | | | | | | | | | | |
| ● | 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 |

> *(continued)* **Status by country**

| Preparatory process[1] | Country[2] | Commission on GRFA[3] | International Undertaking[4] | Convention on Biodiversity[5] | Legislation: Quarantine[6] | Legislation: Plant breeders' rights[7] | Legislation: Seed quality control[8] | National capacity: National programmes[9] | National capacity: Conservation *ex situ*[10] | National capacity: Crop improvement[11] | Subregional network[12] | Genebank accessions[13] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Pacific Region** | | | | | | | | | | | |
| ◑ | Australia | ● | ● | ● | ● | ● | ◐ | ◐ | ◐ | ● | ANZNPGRC | 123,200 |
| ◑ | Cook Islands | ○ | ○ | ● | ○ | | | | ◑ | ◑ | | 91 |
| ○ | Fiji | ○ | ● | ● | | | | | | | | 943 |
| | Kiribati | ○ | ○ | ● | | | | | | | | 14 |
| | Marshall Islands | ○ | ○ | ● | | | ◑ | | | | | |
| | Micronesia | ○ | ○ | ● | | | ◑ | | | | | |
| | Nauru | ○ | ○ | ● | | | | | | | | |
| ○ | New Zealand | ● | ● | ● | ● | ● | ◑ | ● | ◐ | ● | ANZNPGRC | 70,000 |
| ◑ | Niue | ○ | ○ | | ○ | | | | ○ | ○ | | 94 |
| | Palau | ○ | ○ | | | | | | | | | |
| ● | Papua New Guinea | ○ | ○ | ● | ● | | ◐ | | ◑ | ◑ | | 5,656 |
| ● | Samoa | ● | ● | ● | | | | | ◑ | ◑ | | 138 |
| ● | Solomon Islands | ○ | ● | ● | ● | | | | ◑ | ◑ | | 1,130 |
| ● | Tonga | ○ | ● | | ○ | | | | ◑ | ○ | | 8 |
| | Tuvalu | ○ | ○ | ○ | | | | | | | | 40 |
| | Vanuatu | ● | ○ | ● | | | | | | | | 664 |
| | **Americas** | | | | | | | | | | | |
| | **South America** | | | | | | | | | | | |
| ● | 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 |
| | **Central America and Mexico** | | | | | | | | | | | |
| ● | Costa Rica | ● | ● | ● | ● | | ◐ | ◑ | ◐ | ◐ | REM | 5,057 |
| ● | El Salvador | ● | ● | ● | ● | | ◑ | | ◐ | ◐ | REM | 1,547 |
| ● | Guatemala | ● | ○ | ● | ● | | ◑ | | ◑ | ◐ | REM | 2,796 |
| ● | Honduras | ● | ● | ● | ○ | | ◐ | ◐ | ◑ | ◐ | REM | 4,457 |
| ● | Mexico | ● | ● | ● | ● | | ◐ | | ◐ | ● | REM | 103,305 |
| ● | Nicaragua | ● | ● | ○ | ● | | ◐ | | ◐ | ◐ | REM | 2,976 |
| ● | Panama | ● | ● | ● | ● | | ◐ | | ◑ | ◐ | REM | 1,538 |

> *(continued)* **Status by country**

| | | | | | Legislation | | | National capacity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preparatory process**[1] | **Country**[2] | Commission on GRFA[3] | International Undertaking[4] | Convention on Biodiversity[5] | Quarantine[6] | Plant breeders' rights[7] | Seed quality control[8] | National programmes[9] | Conservation *ex situ*[10] | Crop improvement[11] | Subregional network[12] | Genebank accessions[13] |
| | **Caribbean** | | | | | | | | | | | |
| ● | Antigua and Barbuda | ● | ● | ● | ○ | | ◑ | | ○ | ○ | CCM | |
| ● | Bahamas | ● | ● | ● | ○ | | | | ○ | ○ | CCM | |
| ● | Barbados | ● | ● | ● | ● | | | | ◑ | ◑ | CCM | 2,868 |
| | Belize | ● | ● | ● | ● | | | | | | CCM | 80 |
| ● | Cuba | ● | ● | ● | ● | | ◐ | ◐ | ● | ● | | 18,668 |
| ● | Dominica | ● | ● | ● | ○ | | | | ◑ | ◑ | CCM | |
| ● | Dominican Republic | ● | ● | ○ | ● | | ◐ | | ◑ | ◐ | | 2,024 |
| ● | Grenada | ● | ● | ● | ● | | | | ◑ | ◑ | CCM | |
| ◑ | Guyana | ● | ○ | ● | ● | | ◐ | | ◑ | ◑ | TRO | |
| ● | Haiti | ● | ● | ○ | ● | | ◑ | | ○ | ◑ | | |
| ● | 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 |
| | **North America** | | | | | | | | | | | |
| ● | Canada | ● | ○ | ● | ● | ● | ◐ | ◐ | ● | ● | | 212,061 |
| ● | United States | ● | ○ | ○ | ● | ● | ◐ | ● | ● | ● | | 550,000 |

# APPENDIX 2
# List of Major Germplasm Accessions by Crop and Institute

## Legend

Collections of germplasm accessions of major crops are grouped by main crop categories (cereals; food legumes; roots and tubers; vegetables; fruits; oil, sugar, forage, fibre and beverage crops). The collections are listed by institutes (indicated by codes which are listed at the end of the appendix) in descending order of the collection size. The percentage of accessions is the percentage of the genus total. The host country is listed. Alongside, a symbol indicates the type of international agreement the institute has made for its collection, if any:

- ●: the collection, or a designated category thereof, is part of the International Network of *Ex Situ* Collection under the auspices of FAO. This applies to the collection of the International Agricultural Research Centres (IARCs).
- ◑: part of the collection is listed in the IBPGR register of base collections. It has been proposed that this register be merged with the International Network.
- ○: indicates a genebank in a country that has indicated its willingness to place its collections in the International Network.

The storage facilities of the institutes are indicated by the percentage of the institute's collection conserved long-term, medium-term or short-term. Medium-term includes those described as long-term/medium-term, and short-term includes those described as medium-term/short-term. The institute's collection conserved *in vitro* or in field genebanks is also indicated.

LT: long-term.

MT: medium-term.

ST: short-term.

Others: mixed or unknown (LT/MT/ST) and/or field genebank (F) and/or *in vitro* (V) and/or cryopreservation (*) when indicated.

Accessions are categorized by type, expressed as a percentage of the institute's collection: wild species; land races/old cultivars; or advanced cultivars/breeding lines.

| | |
|---|---|
| ws: | wild species. |
| lr/oc: | landraces/old cultivars. |
| ac/bl: | advanced cultivars/breeding lines. |
| Oth: | (others) the type is unknown or a mixture of two or more types. |

Duplication percentage is the percentage of the collection duplicated for safety, where this information has been provided. In most cases, this information is not available.

The information in this Appendix is based on numbers of accessions, or samples, of germplasm. As indicated in Chapter 3, there is much duplication of germplasm between and within collections. Some of this duplication is planned and intended to provide insurance against loss of the original collection. The United States W-6 collection of *Phaseolus*, for example, is a duplicate of that found in NSSL.

Some duplication, however, is unplanned, the result of routine germplasm exchanges in some cases and poor management of collections in other cases. No attempt has been made in this appendix to account for duplication or to present data only on unique accessions. Sufficient information does not exist to do so.

In some cases country names on the table have had to be abbreviated for reasons of space. Full names of the institutes mentioned in the following table are given in the list of acronyms at the end of this appendix.

## Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Cereals** | | | | | | | | | | | | | | | |
| Wheat | *Triticum* | CIMMYT | CGIAR | ● | 98,905 | 13 | 0 | 100 | 0 | 0 | 5 | 37 | 58 | 0 | 50 |
| Wheat | *Triticum* | NSGC | USA | ◑ | 43,285 | 5 | 0 | 100 | 0 | 0 | 2 | 5 | 0 | 93 | - |
| Wheat | *Triticum* | VIR | Russia | ◑ | 35,959 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | IDG | Italy | ○ | 32,751 | 4 | 0 | 100 | 0 | 0 | 2 | 98 | 0 | 0 | - |
| Wheat | *Triticum* | TAMAWC | Australia | | 27,000 | 3 | 100 | 0 | 0 | 0 | 36 | 22 | 42 | 0 | 80 |
| Wheat | *Triticum* | IAB | Ukraine | | 20,000 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | ICARDA | CGIAR | ● | 27,684 | 4 | 40 | 60 | 0 | 0 | 6 | 86 | 8 | 0 | 28 |
| Wheat | *Triticum* | PGRC | Canada | ◑ | 17,177 | 2 | 0 | 100 | 0 | 0 | 14 | 0 | 0 | 86 | - |
| Wheat | *Triticum* | CNPT | Brazil | | 17,090 | 2 | 0 | 100 | 0 | 0 | 2 | 0 | 0 | 98 | - |
| Wheat | *Triticum* | PD-WHEAT | India | ○ | 17,000 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | - |
| Wheat | *Triticum* | BGRC | Germany | ○ | 16,610 | 2 | 0 | 100 | 0 | 0 | 0 | 28 | 72 | 0 | - |
| Wheat | *Triticum* | NBPGR | India | ◑ | 16,440 | 2 | 100 | 0 | 0 | 0 | 2 | 0 | 0 | 98 | - |
| Wheat | *Triticum* | IPK-I | Germany | ○ | 16,184 | 2 | 5 | 95 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | IGB | Israel | | 14,150 | 2 | 100 | 0 | 0 | 0 | 30 | 4 | 39 | 27 | - |
| Wheat | *Triticum* | SPII | Iran | | 12,169 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | PGRC-E | Ethiopia | ○ | 10,745 | 1 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 7 |
| Wheat | *Triticum* | INRA- Clermon | France | ○ | 10,715 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | ICGR-CAAS | China | ◑ | 10,427 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | IHAR | Poland | | 9,956 | 1 | 0 | 100 | 0 | 0 | 0 | 1 | 7 | 92 | - |
| Wheat | *Triticum* | IPSR | UK | ○ | 9,479 | 1 | 0 | 100 | 0 | 0 | 0 | 40 | 43 | 17 | - |
| Wheat | *Triticum* | IPGR | Bangladesh | ○ | 9,347 | 1 | 0 | 93 | 0 | 7 | 0 | 12 | 13 | 75 | - |
| Wheat | *Triticum* | RICP-GP | Czech Rep. | ○ | 8,135 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 7 | 93 | - |
| Wheat | *Triticum* | ARI | Albania | | 8,000 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | - |
| Wheat | *Triticum* | KROME | Czech Rep. | ○ | 7,937 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Wheat | *Triticum* | Others | | | 291,509 | 37 | | | | | | | | | |
| **Wheat** | ***Triticum*** | **Total** | | | **788,654** | **100** | **13** | **48** | **4** | **35** | **3** | **18** | **19** | **60** | |
| Wheat | *Aegilops* | VIR | Russia | ◑ | 3,255 | 15 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Wheat | *Aegilops* | ICARDA | CGIAR | ● | 2,855 | 13 | 40 | 60 | 0 | 0 | 100 | 0 | 0 | 0 | 92 |
| Wheat | *Aegilops* | TELAVUN | Israel | | 2,500 | 12 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Wheat | *Aegilops* | KYOPGI | Japan | ○ | 2,396 | 11 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | |
| Wheat | *Aegilops* | GGB | Greece | | 1,209 | 6 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Wheat | *Aegilops* | WRS | Canada | | 1,100 | 5 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Wheat | *Aegilops* | INRA-Rennes | France | ○ | 1,070 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Wheat | *Aegilops* | TAMAWC | Australia | | 1,050 | 5 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 80 |
| Wheat | *Aegilops* | Others | | | 5,925 | 28 | | | | 100 | | | | 100 | |
| **Wheat** | ***Aegilops*** | **Total** | | | **21,360** | **100** | **10** | **40** | **0** | **44** | **51** | **0** | **0** | **44** | |
| Wheat | *Triticale* | CIMMYT | CGIAR | ● | 15,200 | 38 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 60 |
| Wheat | *Triticale* | SRSFAC | Canada | | 5,700 | 14 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Wheat | *Triticale* | VIR | Russia | ◑ | 4,593 | 11 | 0 | 0 | 0 | 100 | 0 | 0 | 7 | 93 | - |
| Wheat | *Triticale* | LUBLIN | Poland | | 1,877 | 5 | 0 | 25 | 0 | 75 | 0 | 0 | 29 | 71 | - |
| Wheat | *Triticale* | NSGC | USA | ◑ | 1,015 | 3 | 0 | 100 | 0 | 0 | 2 | 5 | 2 | 91 | - |
| Wheat | *Triticale* | Others | | | 11,746 | 29 | | | | 100 | | | | 100 | |
| **Wheat** | ***Triticale*** | **Total** | | | **40,131** | **100** | **0** | **56** | **0** | **44** | **0** | **0** | **54** | **46** | |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Cereals** | | | | | | | | | | | | | | | |
| Rice | *Oryza* | IRRI | CGIAR | ● | 80,634 | 19 | 100 | 0 | 0 | 0 | 3 | 95 | 2 | 0 | 76 |
| Rice | *Oryza* | ICR-SAAS | China | | 20,000 | 5 | 0 | 0 | 100 | 0 | 0 | 16 | 19 | 65 | - |
| Rice | *Oryza* | CRRI | India | ○ | 20,000 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | NSGC | USA | ◑ | 19,646 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | WARDA | CGIAR | ● | 17,440 | 4 | 0 | 0 | 100 | 0 | 5 | 29 | 66 | 0 | 65 |
| Rice | *Oryza* | ICGR-CAAS | China | ◑ | 16,885 | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | NRSSL | Thailand | | 15,350 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | NBPGR | India | ◑ | 12,872 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | IITA | CGIAR | ● | 12,315 | 3 | 50 | 50 | 0 | 0 | 1 | 92 | 6 | 0 | 42 |
| Rice | *Oryza* | NIAR | Japan | ◑ | 11,559 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | NSSL | USA | ◑ | 10,833 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | CNPAF | Brazil | | 8,998 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | Univ-Kyushu | Japan | ○ | 8,000 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | CIRAD | France | ○ | 7,306 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | IRCT-CIRAD | France | ○ | 7,131 | 2 | 0 | 0 | 0 | 100 | 32 | 11 | 57 | 0 | - |
| Rice | *Oryza* | IORR-JAAS | China | | 6,900 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | CRIA | Indonesia | ○ | 5,917 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | RRC | Malaysia | | 5,333 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rice | *Oryza* | CENARGEN | Brazil | ◑ | 4,734 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Rice | *Oryza* | BRRI | Bangladesh | ○ | 4,265 | 1 | 0 | 87 | 13 | 0 | 1 | 87 | 12 | 0 | - |
| Rice | *Oryza* | Others | | | 124,223 | 30 | | | | | | | | | |
| **Rice** | ***Oryza*** | **Total** | | | **420,341** | **100** | **34** | **22** | **13** | **31** | **1** | **25** | **9** | **65** | |
| Maize | *Zea* | IARI-Maize | India | ○ | 25,000 | 10 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | VIR | Russia | ◑ | 18,337 | 7 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | |
| Maize | *Zea* | NSSL | USA | ◑ | 14,091 | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | CIMMYT | CGIAR | ● | 13,070 | 5 | 100 | 0 | 0 | 0 F | 0 | 98 | 2 | 0 | 80 |
| Maize | *Zea* | INIFAP | Mexico | | 10,828 | 4 | 0 | 100 | 0 | 0 | 2 | 98 | 0 | 0 | - |
| Maize | *Zea* | CIFAP-MEX | Mexico | | 9,988 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | NC-7 | USA | ◑ | 8,028 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 70 |
| Maize | *Zea* | YIPB | Ukraine | | 8,000 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | ICGR-CAAS | China | ◑ | 7,999 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | MRIZP | Yugoslavia | | 5,475 | 2 | 0 | 100 | 0 | 0 | 0 | 54 | 46 | 0 | - |
| Maize | *Zea* | BPGV-DRAEDM | Portugal | | 5,283 | 2 | 55 | 45 | 0 | 0 | 0 | 45 | 55 | 0 | - |
| Maize | *Zea* | ICA-Region 4 | Colombia | | 5,043 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | BERGAMO | Italy | | 4,516 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Maize | *Zea* | INRA-Montp | France | ○ | 4,139 | 2 | 0 | 100 | 0 | 0 | 0 | 28 | 64 | 8 | - |
| Maize | *Zea* | LIMAGRAIN | France | ○ | 4,000 | 2 | 0 | 0 | 100 | 0 | 0 | 37 | 63 | 0 | - |
| Maize | *Zea* | NIAR | Japan | ◑ | 3,987 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | UNA-L.MOLINA | Peru | | 3,680 | 1 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| Maize | *Zea* | DF-GUAV | Spain | ○ | 3,057 | 1 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| Maize | *Zea* | INTA-EEA-PER | Argentina | ◑ | 3,000 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | NPGRL | Philippines | ○ | 2,764 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Maize | *Zea* | Others | | | 101,299 | 39 | | | | | | | | | |
| **Maize** | ***Zea*** | **Total** | | | **261,584** | **100** | **25** | **38** | **10** | **26** | **0** | **17** | **11** | **65** | |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Cereals** | | | | | | | | | | | | | | | |
| *Sorghum* | *Sorghum* | ICRISAT | CGIAR | ● | 35,186 | 21 | 20 | 80 | 0 | 0 | 1 | 84 | 12 | 3 | 42 |
| *Sorghum* | *Sorghum* | NSSL | USA | ◑ | 18,971 | 11 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | S-9 | USA | ◑ | 15,434 | 9 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | VIR | Russia | ◑ | 9,892 | 6 | 0 | 0 | 0 | 100 | 2 | 0 | 98 | 0 | - |
| *Sorghum* | *Sorghum* | PGRC-E | Ethiopia | ○ | 7,260 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 11 |
| *Sorghum* | *Sorghum* | DTCP-CSIRO | Australia | | 7,000 | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| *Sorghum* | *Sorghum* | CNPMS | Brazil | | 6,589 | 4 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | - |
| *Sorghum* | *Sorghum* | ICGR-CAAS | China | ◑ | 5,263 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | USDA | Puerto Rico | | 4,000 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | ASP | Yemen | ○ | 4,000 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | INTA-EEAMANF | Argentina | ◑ | 3,900 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | ARC-Sudan | Sudan | | 3,145 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | CIFAP-MEX | Mexico | | 3,000 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| *Sorghum* | *Sorghum* | NRC-Sorghum | India | ○ | 2,767 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | SAARI | Uganda | | 2,635 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | NIAR | Japan | ◑ | 2,583 | 2 | 99 | 0 | 0 | 1 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | INIA-Iguala | Mexico | ◑ | 2,500 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | NPGRL | Philippines | ○ | 2,285 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Sorghum* | *Sorghum* | CENARGEN | Brazil | ◑ | 2,276 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| *Sorghum* | *Sorghum* | Others | | | 29,864 | 18 | | | | | | | | | |
| **Sorghum** | ***Sorghum*** | **Total** | | | **168,550** | **100** | **25** | **31** | **17** | **27** | **0** | **18** | **21** | **61** | |
| Millet | *Eleusine* | Univ-AgrSc | India | ○ | 4,490 | 31 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 1 |
| Millet | *Eleusine* | ICRISAT | CGIAR | ● | 2,848 | 20 | 20 | 80 | 0 | 0 | 1 | 98 | 1 | 0 | 4 |
| Millet | *Eleusine* | NARS | Kenya | | 1,526 | 11 | 0 | 100 | 0 | 0 | 0 | 84 | 16 | 0 | - |
| Millet | *Eleusine* | SAARI | Uganda | | 1,231 | 9 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Millet | *Eleusine* | NSSL | USA | ◑ | 1,212 | 8 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Millet | *Eleusine* | Others | | | 3,153 | 22 | | | | 100 | | | | 100 | |
| **Millet** | ***Eleusine*** | **Total** | | | **14,460** | **100** | **12** | **35** | **31** | **22** | **0** | **28** | **2** | **70** | |
| Millet | *Eragrostis* | PGRC-E | Ethiopia | ◑ | 3,109 | 80 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 10 |
| Millet | *Eragrostis* | Others | | | 797 | 20 | | | | 100 | | | | 100 | |
| **Millet** | ***Eragrostis*** | **Total** | | | **3,906** | **100** | **0** | **80** | **0** | **20** | **0** | **80** | **0** | **20** | |
| Pearl millet | *Pennisetum* | ICRISAT | CGIAR | ● | 21,191 | 58 | 20 | 80 | 0 | 0 | 3 | 92 | 1 | 4 | 20 |
| Pearl millet | *Pennisetum* | SRCPS | USA | ◑ | 5,228 | 14 | 0 | 87 | 0 | 13 F | 13 | 0 | 0 | 87 | - |
| Pearl millet | *Pennisetum* | ORSTOM-Montp | France | ○ | 4,405 | 12 | 0 | 0 | 0 | 100 | 8 | 0 | 92 | 0 | - |
| Pearl millet | *Pennisetum* | PGRC | Canada | ◑ | 3,840 | 10 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pearl millet | *Pennisetum* | SAARI | Uganda | | 2,142 | 6 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| **Pearl millet** | ***Pennisetum*** | **Total** | | | **36,806** | **100** | **12** | **69** | **6** | **14** | **5** | **53** | **12** | **31** | |
| Millet | *Setaria* | ICGR-CAAS | China | ◑ | 6,696 | 19 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Millet | *Setaria* | VIR | Russia | ◑ | 4,745 | 14 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |

> *(continued)* **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Cereals** | | | | | | | | | | | | | | | |
| Millet | *Setaria* | ORSTOM-Montp | France | | 3,500 | 10 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Millet | *Setaria* | ICRISAT | CGIAR | | 1,404 | 4 | 20 | 80 | 0 | 0 | 1 | 98 | 1 | 0 | 4 |
| Millet | *Setaria* | Univ-AgrSc | India | | 1,300 | 4 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 1 |
| Millet | *Setaria* | Others | | | 17,487 | 50 | | | | 100 | | | | 100 | |
| **Millet** | ***Setaria*** | **Total** | | | **35,132** | **100** | **40** | **53** | **7** | **0** | **0** | **8** | **0** | **92** | |
| **Millet** | ***Millet*** | **Total** | | | **90,304** | **100** | **22** | **58** | **10** | **10** | **2** | | **5** | **61** | |
| Barley | *Hordeum* | PGRC | Canada | ◑ | 41,360 | 8 | 0 | 100 | 0 | 0 | 1 | 0 | 0 | 99 | - |
| Barley | *Hordeum* | NSGC | USA | ◑ | 26,019 | 5 | 0 | 100 | 0 | 0 | 10 | 0 | 0 | 90 | - |
| Barley | *Hordeum* | ICARDA | CGIAR | ● | 24,092 | 5 | 40 | 60 | 0 | 0 | 3 | 87 | 10 | 0 | 23 |
| Barley | *Hordeum* | IPSR | UK | ○ | 23,766 | 5 | 0 | 100 | 0 | 0 | 0 | 20 | 18 | 62 | - |
| Barley | *Hordeum* | CENARGEN | Brazil | ◑ | 18,210 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Barley | *Hordeum* | VIR | Russia | ◑ | 17,768 | 4 | 0 | 98 | 0 | 2 | 2 | 0 | 0 | 98 | - |
| Barley | *Hordeum* | NSSL | USA | ◑ | 16,351 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Barley | *Hordeum* | PGRC-E | Ethiopia | ◑ | 12,648 | 3 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| Barley | *Hordeum* | IPK | Germany | ○ | 10,648 | 2 | 97 | 3 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Barley | *Hordeum* | BGRC | Germany | ○ | 9,139 | 2 | 0 | 100 | 0 | 0 | 1 | 53 | 45 | 1 | - |
| Barley | *Hordeum* | CIMMYT | CGIAR | ● | 9,084 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 48 |
| Barley | *Hordeum* | TELAVUN | Israel | | 8,500 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Barley | *Hordeum* | IAB | Ukraine | | 8,000 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Barley | *Hordeum* | TAMAWC | Australia | | 8,000 | 2 | 100 | 0 | 0 | 0 | 6 | 31 | 63 | 0 | 80 |
| Barley | *Hordeum* | SPII | Iran | | 5,006 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Barley | *Hordeum* | SRSFAC | Canada | | 5,000 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Barley | *Hordeum* | Others | | | 243,133 | 50 | | | | | | | | | |
| **Barley** | ***Hordeum*** | **Total** | | | **486,724** | **100** | **10** | **42** | **2** | **46** | **1** | **10** | **11** | **82** | |
| Chenopodium | *Chenopodium* | IBTA-EE.PATA | Bolivia | | 2,210 | 95 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Chenopodium | *Chenopodium* | Others | | | 105 | 5 | | | | 100 | | | | 100 | |
| ***Chenopodium*** | ***Chenopodium*** | **Total** | | | **2,315** | **7** | **0** | **0** | **95** | **5** | **0** | | **0** | **100** | |
| Oat | *Avena* | PGRC | Canada | ◑ | 31,038 | 14 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | NSSL | USA | ◑ | 21,328 | 10 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | NSGC | USA | ◑ | 21,120 | 9 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | VIR | Russia | ◑ | 14,068 | 6 | 0 | 74 | 0 | 26 | 14 | 1 | 0 | 85 | - |
| Oat | *Avena* | LRSAC | Canada | | 12,000 | 5 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | WRS | Canada | | 9,500 | 4 | 100 | 0 | 0 | 0 | 79 | 21 | 0 | 0 | - |
| Oat | *Avena* | NARS | Kenya | | 9,000 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | SRSFAC | Canada | | 7,500 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Oat | *Avena* | TELAVUN | Israel | | 5,500 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | TAMAWC | Australia | | 5,000 | 2 | 100 | 0 | 0 | 0 | 12 | 30 | 58 | 0 | 80 |
| Oat | *Avena* | GBK | Kenya | | 4,186 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | RCA | Hungary | ◑ | 2,933 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | IGB | Israel | | 2,000 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | - |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Cereals** | | | | | | | | | | | | | | | |
| Oat | *Avena* | KROME | Czech Rep. | ◯ | 1,800 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | IPGR | Bulgaria | ◯ | 1,519 | 1 | 0 | 100 | 0 | 0 | 0 | 1 | 99 | 0 | - |
| Oat | *Avena* | INRA-Rennes | France | ◯ | 1,504 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | ICGR-CAAS | China | ◑ | 1,482 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | CRF | Spain | ◯ | 1,246 | 1 | 0 | 100 | 0 | 0 | 0 | 8 | 0 | 92 | - |
| Oat | *Avena* | IAB | Ukraine | | 1,200 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | IGFRI | India | ◯ | 1,125 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Oat | *Avena* | Others | | | 68,238 | 31 | | | | 100 | | | | 100 | |
| Oat | *Avena* | Others | | | 80,114 | 36 | | | | 100 | | | | 100 | |
| **Oat** | ***Avena*** | **Total** | | | **223,287** | **100** | **19** | **38** | **7** | **72** | **5** | **2** | **6** | **88** | |
| Rye | *Secale* | PGRC | Canada | ◑ | 3,038 | 11 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rye | *Secale* | VIR | Russia | ◑ | 2,915 | 11 | 0 | 98 | 0 | 2 | 0 | 0 | 0 | 100 | - |
| Rye | *Secale* | NSGC | USA | ◑ | 2,508 | 9 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rye | *Secale* | IPK | Germany | ◯ | 2,154 | 8 | 97 | 3 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rye | *Secale* | IHAR | Poland | | 1,432 | 5 | 0 | 100 | 0 | 0 | 0 | 17 | 78 | 5 | - |
| Rye | *Secale* | PAN | Poland | | 1,407 | 5 | 0 | 0 | 0 | 100 | 5 | 0 | 0 | 95 | - |
| Rye | *Secale* | NSSL | USA | ◑ | 1,287 | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rye | *Secale* | IPK-Rye | Germany | ◯ | 1,155 | 4 | 0 | 0 | 100 | 0 | 2 | 10 | 88 | 0 | - |
| Rye | *Secale* | Others | | | 11,236 | 41 | | | | 100 | | | | 100 | |
| **Rye** | ***Secale*** | **Total** | | | **27,132** | **100** | **12** | **36** | **4** | **47** | **0** | **1** | **8** | **90** | |
| **Food legumes** | | | | | | | | | | | | | | | |
| Bean | *Phaseolus* | CIAT | CGIAR | ● | 41,061 | 15 | 50 | 50 | 0 | 0 | 2 | 97 | 1 | 0 | 79 |
| Bean | *Phaseolus* | W-6 | USA | | 11,501 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | INIFAP | Mexico | | 10,570 | 4 | 0 | 0 | 0 | 100 | 6 | 19 | 0 | 75 | - |
| Bean | *Phaseolus* | NSSL | USA | ◑ | 10,066 | 4 | 49 | 0 | 0 | 51 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | INIA | Mexico | ◑ | 10,000 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | IPK | Germany | ◯ | 6,505 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | CNPAF | Brazil | | 9,009 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | CENARGEN | Brazil | ◑ | 6,508 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 14 | 86 | - |
| Bean | *Phaseolus* | VIR | Russia | ◑ | 6,157 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | BCA | Malawi | | 6,000 | 2 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | - |
| Bean | *Phaseolus* | EMBRAPA | Brazil | | 4,202 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | NYSAES | USA | | 4,000 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | RCA | Hungary | ◑ | 3,991 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | LBN | Indonesia | ◯ | 3,846 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | ISAR | Rwanda | | 3,075 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Bean | *Phaseolus* | Others | | | 131,878 | 49 | | | | | | | | | - |
| **Bean** | ***Phaseolus*** | **Total** | | | **268,369** | **100** | **14** | **29** | **5** | **53** | **1** | **21** | **3** | **76** | **-** |
| Bean | *Psophocarpus* | NBPGR | India | ◯ | 1,100 | 23 | 0 | 0 | 91 | 9 | 0 | 91 | 0 | 9 | - |
| Bean | *Psophocarpus* | Others | | | 3,782 | 77 | | | | 100 | | | | 100 | - |
| **Bean** | ***Psophocarpus*** | **Total** | | | **4,882** | **100** | **0** | **0** | **21** | **79** | **0** | **21** | **0** | **79** | **-** |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Food legumes** | | | | | | | | | | | | | | | |
| Soybean | *Glycine* | ICGR-CAAS | China | ◑ | 15,334 | 9 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | AVRDC | Regional | | 12,916 | 7 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | |
| Soybean | *Glycine* | NSSL | USA | ◑ | 10,880 | 6 | 100 | 0 | 0 | 0 | 6 | 0 | 0 | 94 | - |
| Soybean | *Glycine* | SOY-N | USA | | 8,368 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 4 | 96 | |
| Soybean | *Glycine* | IAB | Ukraine | | 7,000 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | VIR | Russia | ◑ | 5,462 | 3 | 0 | 0 | 94 | 6 | 6 | 0 | 0 | 94 | - |
| Soybean | *Glycine* | SRI-JAAS | China | | 4,800 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | CSIRO | Australia | | 2,000 | 1 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Soybean | *Glycine* | CENARGEN | Brazil | ◑ | 4,693 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Soybean | *Glycine* | SOY | India | ○ | 4,022 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | UCRD | Rep. Korea | | 4,020 | 2 | 0 | 100 | 0 | 0 | 9 | 0 | 0 | 91 | - |
| Soybean | *Glycine* | NIAR | Japan | ◑ | 3,741 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | TARI | Regional | | 3,596 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | SOY-S | USA | ◑ | 3,374 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| Soybean | *Glycine* | IPK-I | Germany | | 3,065 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | CNPSO | Brazil | | 2,887 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Soybean | *Glycine* | NRCS-Soy | India | ○ | 2,500 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | CBICAU | Zimbabwe | | 2,236 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | SRI-FC | Indonesia | ○ | 2,198 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | NBPGR-Akola | India | ○ | 2,171 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | Univ-Nanjing | China | | 2,168 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | HAAS | China | | 1,955 | 1 | 0 | 0 | 0 | 100 | 0 | 26 | 53 | 21 | - |
| Soybean | *Glycine* | INIFAP | Mexico | | 1,800 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | NPGRL | Philippines | ○ | 1,764 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Soybean | *Glycine* | Others | | | 63,450 | 36 | | | | | | | | | |
| **Soybean** | ***Glycine*** | **Total** | | | **176,400** | **100** | **24** | **25** | **8** | **42** | **1** | **2** | **7** | **91** | |
| Chickpea | *Cicer* | ICRISAT | CGIAR | ● | 17,244 | 25 | 20 | 80 | 0 | 0 | 1 | 93 | 4 | 2 | 98 |
| Chickpea | *Cicer* | ICARDA | CGIAR | ● | 9,974 | 14 | 40 | 60 | 0 | 0 | 3 | 72 | 25 | 0 | 51 |
| Chickpea | *Cicer* | SPII | Iran | | 4,925 | 7 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | W-6 | USA | | 3,806 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | PGRI-NARC | Pakistan | ○ | 2,912 | 4 | 0 | 100 | 0 | 0 | 1 | 0 | 0 | 99 | - |
| Chickpea | *Cicer* | NARC-Paki | Pakistan | ○ | 2,584 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | ATFGRC | Australia | | 2,500 | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | VIR | Russia | ◑ | 2,293 | 3 | 0 | 99 | 0 | 1 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | NSSL | USA | ◑ | 2,031 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | IARI | India | ○ | 2,000 | 3 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Chickpea | *Cicer* | INIA-Iguala | Mexico | ◑ | 1,600 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | CIDACOR | Spain | ○ | 1,500 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Chickpea | *Cicer* | ENMP-Past | Portugal | | 1,500 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Chickpea | *Cicer* | Univ-Tehran | Iran | | 1,200 | 2 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Chickpea | *Cicer* | Others | | | 13,667 | 20 | | | | 100 | | | | 100 | - |
| **Chickpea** | ***Cicer*** | **Total** | | | **69,736** | **100** | **11** | **53** | **2** | **31** | **1** | **38** | **7** | **51** | |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Food legumes** | | | | | | | | | | | | | | | |
| Lentil | *Lens* | ICARDA | CGIAR | ● | 7,911 | 29 | 40 | 60 | 0 | 0 | 5 | 79 | 15 | 0 | 91 |
| Lentil | *Lens* | VIR | Russia | ◑ | 2,358 | 9 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Lentil | *Lens* | W-6 | USA | ◑ | 2,259 | 8 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| Lentil | *Lens* | SPII | Iran | | 1,885 | 7 | 17 | 83 | 0 | 0 | 17 | 83 | 0 | 0 | - |
| Lentil | *Lens* | ATFGRC | Australia | | 1,400 | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Lentil | *Lens* | Others | | | 11,611 | 42 | | | | 100 | | | | 100 | - |
| **Lentil** | ***Lens*** | **Total** | | | **27,424** | **100** | **13** | **31** | **0** | **51** | **3** | **28** | **4** | **59** | |
| Faba bean | *Vicia* | ICARDA | CGIAR | ● | 9,703 | 30 | 40 | 60 | 0 | 0 | 0 | 98 | 2 | 0 | 35 |
| Faba bean | *Vicia* | IDG | Italy | ○ | 3,671 | 12 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | IPK | Germany | ○ | 2,946 | 9 | 74 | 26 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | ATFCGRC | Australia | | 2,500 | 8 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | BGRC | Germany | ○ | 2,287 | 7 | 0 | 88 | 0 | 12 | 2 | 32 | 62 | 4 | - |
| Faba bean | *Vicia* | CIDACOR | Spain | ○ | 1,900 | 6 | 0 | 100 | 0 | 0 | 0 | 0 | 63 | 37 | - |
| Faba bean | *Vicia* | VIR | Russia | ◑ | 1,707 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | INRA-Rennes | France | ○ | 1,700 | 5 | 0 | 0 | 0 | 100 | 0 | 59 | 41 | 0 | - |
| Faba bean | *Vicia* | UC-ICN | Ecuador | | 1,650 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | AARI | Turkey | | 1,495 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Faba bean | *Vicia* | PGRC-E | Ethiopia | ◑ | 1,208 | 4 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Faba bean | *Vicia* | SUMPERK | Czech Rep. | ○ | 1,064 | 3 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| **Faba bean** | ***Vicia*** | **Total** | | | **31,831** | **100** | **19** | **38** | **3** | **32** | **0** | **39** | **11** | **42** | **-** |
| Pea | *Pisum* | IPSR | UK | ○ | 5,000 | 7 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | IDG | Italy | ○ | 4,090 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | ATFCGRC | Australia | | 3,300 | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | SOAFD | UK | ○ | 2,894 | 4 | 0 | 100 | 0 | 0 | 3 | 24 | 71 | 2 | - |
| Pea | *Pisum* | NE-9 | USA | | 2,892 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | SHRWIAT | Poland | | 2,874 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | DHSNYST | USA | | 2,694 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | IPK | Germany | ○ | 2,347 | 3 | 94 | 6 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | BGRC | Germany | ○ | 2,332 | 3 | 0 | 64 | 0 | 36 | 2 | 17 | 72 | 9 | - |
| Pea | *Pisum* | DAFS | UK | ○ | 1,700 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | IFVCNS | Yugoslavia | | 1,578 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| Pea | *Pisum* | NSSL | USA | ◑ | 1,449 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | NBPGR | India | ○ | 1,400 | 2 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Pea | *Pisum* | SIAVA | Spain | ○ | 1,300 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | RCA | Hungary | ◑ | 1,259 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | IHAR | Poland | | 1,173 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | SUMPERK | Czech Rep. | ○ | 1,145 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | RICP-Prague | Czech Rep. | ○ | 1,093 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Pea | *Pisum* | PGRC-E | Ethiopia | ◑ | 1,011 | 1 | 0 | 0 | 0 | 100 | 0 | 57 | 0 | 43 | - |
| Pea | *Pisum* | Others | | | 33,757 | 45 | | | | 100 | | | | 100 | - |
| **Pea** | ***Pisum*** | **Total** | | | **75,288** | **100** | **10** | **19** | **2** | **66** | **0** | **4** | **7** | **84** | |

**> (continued)** **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Food legumes** | | | | | | | | | | | | | | | |
| Groundnut | *Arachis* | ICRISAT | CGIAR | ● | 14,957 | 18 | 20 | 80 | 0 | 0 | 3 | 59 | 33 | 5 | 28 |
| Groundnut | *Arachis* | NRCG | India | ○ | 7,935 | 10 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | PC-Groundnut | India | | 6,274 | 8 | 0 | 0 | 100 | 0 | 1 | 0 | 0 | 99 | - |
| Groundnut | *Arachis* | S-9 | USA | | 6,233 | 8 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | NSSL | USA | ◑ | 4,232 | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | NCSTUNCS | USA | | 3,788 | 5 | 100 | 0 | 0 | 0 | 7 | 0 | 42 | 51 | - |
| Groundnut | *Arachis* | IOCR-CAAS | China | ◑ | 2,403 | 3 | 0 | 0 | 0 | 100 | 1 | 74 | 25 | 0 | - |
| Groundnut | *Arachis* | INTA-EEAMANF | Argentina | ◑ | 2,300 | 3 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | INTAMAN | Argentina | ◑ | 2,235 | 3 | 0 | 0 | 0 | 100 | 1 | 88 | 12 | -1 | - |
| Groundnut | *Arachis* | ICGR-CAAS | China | ◑ | 2,186 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | CRIFC | Indonesia | ○ | 1,730 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | TAES | USA | | 1,667 | 2 | 0 | 0 | 100 | 0 | 18 | 0 | 82 | 0 | - |
| Groundnut | *Arachis* | NPGRL | Philippines | ○ | 1,355 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | VIR | Russia | ◑ | 1,200 | 1 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | IFC-GAAS | China | | 1,176 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Groundnut | *Arachis* | Others | | | 21,515 | 27 | | | | 100 | | | | 100 | - |
| **Groundnut** | ***Arachis*** | **Total** | | | **81,186** | **100** | **16** | **17** | **14** | **53** | **1** | **15** | **11** | **72** | |
| Bambara groundnut | *Vigna* | IITA | CGIAR | ● | 2,035 | 59 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 17 |
| Bambara groundnut | *Vigna* | ORSTOM-Montp | France | | 1,416 | 41 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Bambara groundnut | *Vigna* | Others | | | | 0 | | | | 100 | | | | 100 | - |
| **Bambara groundnut** | ***Vigna*** | **Total** | | | **3,451** | **100** | **59** | **0** | **0** | **41** | **0** | **100** | **0** | **0** | |
| Cowpea | *Vigna* | IITA | CGIAR | ● | 16,467 | 19 | 50 | 50 | 0 | 0 | 10 | 86 | 4 | 0 | 30 |
| Cowpea | *Vigna* | NPGRL | Philippines | ◑ | 9,405 | 11 | 0 | 100 | 0 | 0 | 0 | 0 | 1 | 99 | - |
| Cowpea | *Vigna* | S-9 | USA | ◑ | 8,437 | 10 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | AVRDC | Regional | ◑ | 5,483 | 6 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | NBPGR | India | ◑ | 4,663 | 5 | 100 | 0 | 0 | 0 | 1 | 24 | 0 | 75 | - |
| Cowpea | *Vigna* | LBN | Indonesia | ○ | 4,130 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | CNPAF | Brazil | | 4,115 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | VIR | Russia | ◑ | 2,283 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | CENARGEN | Brazil | ◑ | 1,855 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | PGRI-NARC | Pakistan | ○ | 1,521 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | DAR | Botswana | | 1,028 | 1 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | - |
| Cowpea | *Vigna* | ARS | Botswana | | 1,028 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cowpea | *Vigna* | Others | | | 25,128 | 29 | | | | 100 | | | | 100 | - |
| **Cowpea** | ***Vigna*** | **Total** | | | **85,543** | **100** | **23** | **44** | **1** | **32** | **2** | **19** | **1** | **78** | **-** |
| Pigeon pea | *Cajanus* | ICRISAT | CGIAR | ● | 12,885 | 52 | 20 | 80 | 0 | 0 | 4 | 77 | 14 | 5 | 22 |
| Pigeon pea | *Cajanus* | S-9 | USA | ◑ | 4,116 | 17 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |

## > (continued) Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | | ws | lr/oc | ac/bl | Oth | % |
| **Food legumes** | | | | | | | | | | | | | | | | |
| Pigeon pea | *Cajanus* | IARI | India | ○ | 1,500 | 6 | 0 | 0 | 0 | 100 | | 0 | 100 | 0 | 0 | - |
| Pigeon pea | *Cajanus* | NARS | Kenya | | 1,080 | 4 | 0 | 100 | 0 | 0 | | 0 | 100 | 0 | 0 | - |
| Pigeon pea | *Cajanus* | Others | | | 5,357 | 21 | | | | 100 | | | | | 100 | - |
| **Pigeon pea** | ***Cajanus*** | **Total** | | | **24,938** | **100** | **10** | **46** | **0** | **44** | | **2** | **50** | **7** | **41** | |
| Lupin | *Lupinus* | SIAEX | Spain | ○ | 2,898 | 9 | 0 | 100 | 0 | 0 | | 76 | 21 | 4 | -1 | - |
| Lupin | *Lupinus* | ATFGRC | Australia | | 2,500 | 8 | 100 | 0 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Lupin | *Lupinus* | INRA-Poitou | France | ○ | 2,046 | 7 | 0 | 100 | 0 | 0 | | 13 | 0 | 87 | 0 | - |
| Lupin | *Lupinus* | UNSAA | Peru | | 1,940 | 6 | 0 | 0 | 0 | 100 | | 7 | 93 | 0 | 0 | - |
| Lupin | *Lupinus* | BGRC | Germany | ○ | 1,873 | 6 | 0 | 100 | 0 | 0 | | 29 | 56 | 15 | 0 | - |
| Lupin | *Lupinus* | CRF | Spain | ○ | 1,554 | 5 | 0 | 99 | 0 | 1 | | 48 | 0 | 0 | 52 | - |
| Lupin | *Lupinus* | RNG | UK | ○ | 1,300 | 4 | 0 | 0 | 100 | 0 | | 0 | 0 | 0 | 100 | - |
| Lupin | *Lupinus* | WADA | Australia | | 1,200 | 4 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Lupin | *Lupinus* | INRA-Rennes | France | ○ | 1,100 | 4 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Lupin | *Lupinus* | SHRWIAT | Poland | | 1,049 | 3 | 100 | 0 | 0 | 0 | | 48 | 0 | 52 | 0 | - |
| Lupin | *Lupinus* | Others | | | 13,402 | 43 | | | | 100 | | | | | 100 | - |
| **Lupin** | ***Lupinus*** | **Total** | | | **30,862** | **100** | **3** | **31** | **4** | **53** | | **14** | **11** | **9** | **58** | |
| **Roots and tubers** | | | | | | | | | | | | | | | | |
| Potato | *Solanum* | CIP | CGIAR | | 6,257 | 20 | 60 | 40 | 0 | 0 | F/V | 25 | 59 | 16 | 0 | 100 |
| Potato | *Solanum* | ICA-Region 1 | Colombia | | 3,361 | 11 | 0 | 0 | 100 | 0 | | 0 | 0 | 0 | 100 | - |
| Potato | *Solanum* | HNA | Japan | | 1,740 | 6 | 0 | 0 | 0 | 100 | | 0 | 0 | 84 | 16 | - |
| Potato | *Solanum* | ROPTA | Netherlands | | 1,610 | 5 | 0 | 0 | 0 | 100 | | 3 | 2 | 0 | 95 | - |
| Potato | *Solanum* | HBROD | Czech Rep. | | 1,356 | 5 | 0 | 0 | 6 | 94 | V | 5 | 0 | 94 | 1 | - |
| Potato | *Solanum* | IPRBON | Poland | | 1,182 | 4 | 0 | 0 | 0 | 100 | | 0 | 0 | 100 | 0 | - |
| Potato | *Solanum* | IBTA-TORALAP | Bolivia | | 1,109 | 4 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Potato | *Solanum* | SOAFD | UK | | 1,100 | 4 | 0 | 0 | 0 | 100 | V | 0 | 0 | 100 | 0 | - |
| Potato | *Solanum* | Others | | | 11,861 | 40 | | | | 100 | | | | | 100 | - |
| **Potato** | ***Solanum*** | **Total** | | | **29,576** | **100** | **12** | **8** | **12** | **67** | | **5** | **12** | **20** | **61** | **-** |
| Sweet potato | *Ipomoea* | CIP | CGIAR | | 6,522 | 21 | 40 | 60 | 0 | 0 | F/V | 18 | 59 | 23 | 0 | 93 |
| Sweet potato | *Ipomoea* | AVRDC | Regional | | 1,382 | 4 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sweet potato | *Ipomoea* | USVL | USA | | 1,282 | 4 | 0 | 0 | 0 | 100 | | 31 | 5 | 64 | 0 | - |
| Sweet potato | *Ipomoea* | HAES | Pap. NG | | 1,231 | 4 | 0 | 0 | 0 | 100 | | 0 | 98 | 2 | 0 | - |
| Sweet potato | *Ipomoea* | IBKNA | Japan | | 1,162 | 4 | 0 | 0 | 0 | 100 | | 25 | 1 | 73 | 1 | - |
| Sweet potato | *Ipomoea* | UCDKNAE | Japan | | 1,151 | 4 | 0 | 0 | 0 | 100 | | 0 | 10 | 75 | 15 | - |
| Sweet potato | *Ipomoea* | Others | | | 19,066 | 60 | | | | 100 | | | | | 100 | - |

> *(continued)* **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Roots and tubers** | | | | | | | | | | | | | | | |
| **Sweet potato** | ***Ipomoea*** | **Total** | | | **31,796** | **100** | **8** | **12** | **0** | **79** | **6** | **16** | **13** | **65** | **-** |
| Cassava | *Manihot* | CIAT | CGIAR | ● | 5,985 | 21 | 0 | 0 | 0 | 100 V | 0 | 82 | 18 | 0 | 90 |
| Cassava | *Manihot* | IITA | CGIAR | ● | 2,330 | 8 | 0 | 100 | 0 | 0 F/V | 11 | 33 | 55 | 0 | - |
| Cassava | *Manihot* | ICAR | India | ○ | 1,327 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | | 100 | - |
| Cassava | *Manihot* | CNPMF | Brazil | | 1,259 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | | 100 | - |
| Cassava | *Manihot* | SAARI | Uganda | | 1,136 | 4 | 0 | 0 | 0 | 100 | 0 | 4 | 96 | 0 | - |
| Cassava | *Manihot* | Others | | | 15,869 | 57 | | | | 100 | | | | 100 | - |
| **Cassava** | ***Manihot*** | **Total** | | | **27,906** | **100** | **0** | **8** | **0** | **92** | **1** | **21** | **12** | **66** | **-** |
| Yam | *Dioscorea* | IITA | CGIAR | ● | 2,875 | 25 | 0 | 100 | 0 | 0 F/V | 0 | 94 | | 0 | 20 |
| Yam | *Dioscorea* | Others | | | 8,625 | 75 | | | | 100 | | | | 100 | |
| **Yam** | ***Dioscorea*** | **Total** | | | **11,500** | **100** | **0** | **25** | **0** | **75** | **0** | **24** | | **75** | **-** |
| **Vegetables** | | | | | | | | | | | | | | | |
| Mustard | *Brassica* | PC-RAPE & MU | India | ○ | 7,314 | 9 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | - |
| Mustard | *Brassica* | HRI | Australia | ○ | 5,146 | 6 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Mustard | *Brassica* | NBPGR | India | ◑ | 4,530 | 5 | 0 | 0 | 49 | 51 | 0 | 0 | 0 | 100 | - |
| Mustard | *Brassica* | ICGR-CAAS | China | ◑ | 2,674 | 3 | 82 | 18 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Mustard | *Brassica* | VIR | Russia | ◑ | 2,035 | 2 | 0 | 100 | 0 | 0 | 0 | 98 | 0 | 2 | - |
| Mustard | *Brassica* | SOAFD | UK | ○ | 1,936 | 2 | 100 | 0 | 0 | 0 | 0 | 52 | 48 | 0 | - |
| Mustard | *Brassica* | IPK | Germany | ○ | 1,294 | 2 | 100 | 0 | 0 | 0 | 4 | 0 | 96 | 0 | - |
| Mustard | *Brassica* | GEVES-Angers | France | ○ | 1,396 | 2 | 0 | 1 | 0 | 99 | 0 | 3 | 97 | 0 | - |
| Mustard | *Brassica* | PGRC | Canada | ◑ | 1,267 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Mustard | *Brassica* | CGN/ CPRO-DLO | Netherlands | ◑ | 1,258 | 2 | 0 | 100 | 0 | 0 | 1 | 22 | 71 | 6 | - |
| Mustard | *Brassica* | DG | India | ○ | 1,200 | 1 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | - |
| Mustard | *Brassica* | BGRC | Germany | ○ | 1,112 | 1 | 0 | 100 | 0 | 0 | 1 | 20 | 79 | 0 | - |
| Mustard | *Brassica* | Others | | | 51,226 | 62 | | | | 100 | | | | 100 | - |
| **Mustard** | ***Brassica*** | **Total** | | | **82,388** | **100** | **13** | **7** | **13** | **67** | **0** | **15** | **6** | **79** | **-** |
| Oleracea | *Brassica* | INRA-Rennes | France | ○ | 1,215 | 41 | 0 | 0 | 0 | 100 | 12 | 0 | 53 | 35 | - |
| Oleracea | *Brassica* | Others | | | 1,740 | 59 | | | | 100 | | | | 100 | - |
| **Oleracea** | ***Brassica*** | **Total** | | | **2,955** | **100** | **0** | **0** | **0** | **100** | **5** | **0** | **22** | **73** | **-** |
| Rape** | *Brassica* | DTCP-CSIRO | Australia | | 4,000 | 19 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rape | *Brassica* | NC-7 | USA | ◑ | 2,877 | 13 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| Rape | *Brassica* | GMO | Rep. Korea | | 2,188 | 10 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | - |
| Rape | *Brassica* | GOTIPP | Germany | ○ | 1,520 | 7 | 0 | 0 | 100 | 0 | 2 | 4 | 94 | 0 | - |
| Rape | *Brassica* | NE-9 | USA | | 1,309 | 6 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Rape | *Brassica* | PGRC-E | Ethiopia | ◑ | 1,069 | 5 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| Rape | *Brassica* | IOCR-CAAS | China | ◑ | 1,010 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Rape | *Brassica* | Others | | | 11,607 | 54 | | | | 100 | | | | 100 | - |

> *(continued)* **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Vegetables** | | | | | | | | | | | | | | | |
| **Rape** | ***Brassica*** | **Total** | | | **21,580** | **100** | **0** | **23** | **17** | **60** | **0** | **19** | **17** | **65** | **-** |
| | ***Brassica*** | **Total** | | | **106,923** | **100** | **10** | **10** | **14** | **66** | **0** | **15** | **9** | **76** | - |
| Tomato | *Lycopersicon* | AVRDC | Regional | | 6,676 | 9 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | NE-9 | USA | | 5,507 | 7 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | |
| Tomato | *Lycopersicon* | DHSNYST | USA | | 4,850 | 6 | 0 | 99 | 0 | 1 | 0 | 1 | 98 | | - |
| Tomato | *Lycopersicon* | Campbell | USA | | 4,572 | 6 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | | - |
| Tomato | *Lycopersicon* | VIR | Russia | ◑ | 3,388 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | | - |
| Tomato | *Lycopersicon* | IPK-I | Germany | ○ | 3,045 | 4 | 94 | 5 | 0 | 1 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | RICP-Prague | Czech Rep. | ○ | 1,788 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | NSSL | USA | ◑ | 1,573 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | BGUPV | Spain | ○ | 1,344 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | CRF | Spain | ○ | 1,267 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Tomato | *Lycopersicon* | GEVES-Angers | France | ○ | 1,254 | 2 | 0 | 0 | 0 | 100 | 0 | 25 | 75 | | - |
| Tomato | *Lycopersicon* | INIFAT | Cuba | | 1,184 | 2 | 0 | 100 | 0 | 0 | 0 | 12 | 88 | | - |
| Tomato | *Lycopersicon* | INTA | Argentina | ◑ | 1,138 | 1 | 0 | 0 | 100 | 0 | 0 | 0 | 2 | 98 | - |
| Tomato | *Lycopersicon* | IFVCNS | Yugoslavia | | 1,030 | 1 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | | - |
| Tomato | *Lycopersicon* | Others | | | 39,760 | 51 | | | | 100 | | | | 100 | - |
| **Tomato** | ***Lycopersicon*** | **Total** | | | **78,376** | **100** | **10** | **15** | **7** | **61** | **51** | **1** | **20** | **22** | **-** |
| *Capsicum* | *Capsicum* | AVRDC | Regional | ◑ | 5,177 | 10 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | IVCP | Bulgaria | ○ | 4,089 | 8 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | - |
| *Capsicum* | *Capsicum* | CIFAP-CEL | Mexico | | 3,590 | 7 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | INIFAP | Mexico | | 3,590 | 7 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | S-9 | USA | ◑ | 3,147 | 6 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | VIR | Russia | ◑ | 1,800 | 3 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | - |
| *Capsicum* | *Capsicum* | TSS | Regional | | 1,800 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| *Capsicum* | *Capsicum* | NPGRL | Philippines | ○ | 1,584 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | INIFAP-BG | Mexico | | 1,500 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | INRA-Avign-M | France | ○ | 1,371 | 3 | 0 | 99 | 0 | 1 | 1 | 88 | 0 | 11 | - |
| *Capsicum* | *Capsicum* | INIA-GNorte | Mexico | ◑ | 1,241 | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 97 | 3 | - |
| *Capsicum* | *Capsicum* | IPK-I | Germany | ○ | 1,177 | 2 | 81 | 19 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | CATIE | Costa Rica | ◑ | 1,112 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | VEGTBUD | Hungary | | 1,069 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Capsicum* | *Capsicum* | IFVCNS | Yugoslavia | | 1,055 | 2 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | - |
| *Capsicum* | *Capsicum* | DGABGHZ | Spain | ○ | 1,035 | 2 | 100 | 0 | 0 | 0 | 2 | 0 | 0 | 98 | - |
| *Capsicum* | *Capsicum* | Others | | | 19,221 | 36 | | | | 100 | | | | 100 | - |
| ***Capsicum*** | ***Capsicum*** | **Total** | | | **53,558** | **100** | **4** | **31** | **17** | **48** | **0** | **6** | **15** | **79** | **-** |
| *Allium* | *Allium* | IPK-Taxo | Germany | ○ | 4,100 | 16 | 0 | 100 | 0 | 0 F | 0 | 0 | 0 | 100 | - |
| *Allium* | *Allium* | NBPGR | India | ◑ | 2,067 | 8 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | - |
| *Allium* | *Allium* | HRI | UK | ○ | 1,825 | 7 | 100 | 0 | 0 | 0 | 0 | 0 | 67 | 33 | - |

## > (continued) Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | | ws | lr/oc | ac/bl | Oth | % |
| **Vegetables** | | | | | | | | | | | | | | | | |
| *Allium* | *Allium* | VIR | Russia | ○ | 1,303 | 5 | 0 | 100 | 0 | 0 | | 0 | 86 | 14 | 0 | - |
| *Allium* | *Allium* | Others | | | 15,993 | 63 | | | | 100 | | | | | 100 | - |
| ***Allium*** | ***Allium*** | **Total** | | | **25,288** | **100** | **7** | **21** | **8** | **63** | | **0** | **13** | **6** | **82** | **-** |
| *Cucurbita* | *Cucurbita* | CATIE | Costa Rica | ◑ | 2,022 | 12 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| *Cucurbita* | *Cucurbita* | VIR | Russia | ◑ | 2,000 | 12 | 0 | 100 | 0 | 0 | | 0 | 100 | 0 | 0 | - |
| *Cucurbita* | *Cucurbita* | RCA | Hungary | ◑ | 1,246 | 7 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| *Cucurbita* | *Cucurbita* | NSSL | USA | ◑ | 1,220 | 7 | 100 | | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| *Cucurbita* | *Cucurbita* | S-9 | USA | ◑ | 1,162 | 7 | 0 | 100 | 0 | 0 | | 0 | 100 | 0 | 0 | - |
| *Cucurbita* | *Cucurbita* | CNPH | Brazil | | 1,070 | 6 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| *Cucurbita* | *Cucurbita* | Others | | | 8,589 | 50 | | | | 100 | | | | | 100 | - |
| ***Cucurbita*** | ***Cucurbita*** | **Total** | | | **17,309** | **100** | **7** | **43** | **0** | **50** | | **0** | **18** | **0** | **82** | **-** |
| Eggplant | *Solanum* | VIR | Russia | ◑ | 10,135 | 11 | 0 | | 0 | 100 | | 0 | 0 | 7 | 93 | - |
| Eggplant | *Solanum* | TARI | Regional | | 1,298 | 1 | 0 | | 0 | 99 | | 0 | 0 | 1 | 99 | - |
| Eggplant | *Solanum* | ICGR-CAAS | China | ◑ | 1,093 | 1 | 36 | | 0 | 64 | V | 0 | 0 | 0 | 100 | - |
| Eggplant | *Solanum* | IPB-UPLB | Philippines | ◑ | 1,081 | 1 | 0 | 21 | 0 | 79 | | 0 | 0 | 79 | 21 | - |
| Eggplant | *Solanum* | Others | | | 78,172 | 85 | | | | 100 | | | | | 100 | - |
| **Eggplant** | ***Solanum*** | **Total** | | | **91,779** | **100** | **0** | | **0** | **99** | | **0** | **0** | **2** | **98** | **-** |
| Melon | *Citrullus* | VIR | Russia | ◑ | 2,500 | 57 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Melon | *Citrullus* | S-9 | USA | ◑ | 1,429 | 32 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Melon | *Citrullus* | Others | | | 468 | 11 | | | | 100 | | | | | 100 | - |
| **Melon** | ***Citrullus*** | **Total** | | | **4,397** | **100** | **0** | **89** | **0** | **11** | | **0** | **0** | **0** | **100** | **-** |
| Okra | *Abelmoschus* | S-9 | USA | ◑ | 1,712 | 26 | 0 | 100 | 0 | 0 | | 0 | 100 | 0 | 0 | - |
| Okra | *Abelmoschus* | ORSTOM | Côte d'Ivoire | | 1,430 | 22 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Okra | *Abelmoschus* | Others | | | 3,388 | 52 | | | | 100 | | | | | 100 | - |
| **Okra** | ***Abelmoschus*** | **Total** | | | **6,530** | **100** | **0** | **48** | **0** | **52** | | **0** | **26** | **0** | **74** | **-** |
| Radish | *Raphanus* | VIR | Russia | ◑ | 1,200 | 22 | 0 | 100 | 0 | 0 | | 0 | 100 | 0 | 0 | - |
| Radish | *Raphanus* | Others | | | 4,232 | 78 | | | | 100 | | | | | 100 | - |
| **Radish** | ***Raphanus*** | **Total** | | | **5,432** | **100** | **0** | **22** | **0** | **78** | | **0** | **22** | **0** | **78** | **-** |
| Carrot | *Daucus* | VIR | Russia | ◑ | 1,700 | 29 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Carrot | *Daucus* | HRI | UK | ○ | 1,425 | 24 | 100 | | 0 | 0 | | 34 | 0 | 66 | 0 | - |
| Carrot | *Daucus* | Others | | | 2,756 | 47 | | | | 100 | | | | | 100 | - |
| **Carrot** | ***Daucus*** | **Total** | | | **5,881** | **100** | **24** | **29** | **0** | **47** | | **8** | **0** | **16** | **76** | **-** |
| **Fruits** | | | | | | | | | | | | | | | | |
| Apple | *Malus* | IOP-JAAS | China | ◑ | 30,780 | 32 | 0 | 0 | 0 | 100 | | 0 | 0 | 100 | 0 | - |
| Apple | *Malus* | KRSAC | Canada | | 11,077 | 11 | 0 | 0 | 0 | 100 | F | 0 | 0 | 100 | 0 | - |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | | ws | lr/oc | ac/bl | Oth | % |
| **Fruits** | | | | | | | | | | | | | | | | |
| Apple | *Malus* | DFBBAL | Sweden | ○ | 9,012 | 9 | 0 | 0 | 0 | 100 | F | 0 | 7 | 4 | 89 | - |
| Apple | *Malus* | VIR | Russia | ◑ | 2,500 | 3 | 0 | 0 | 0 | 100 | | 0 | 0 | 100 | 0 | - |
| Apple | *Malus* | NFC | UK | ○ | 2,174 | 2 | 0 | 0 | 0 | 100 | F | 0 | 96 | 0 | 4 | - |
| Apple | *Malus* | INRA-ANGERS | France | ○ | 1,895 | 2 | 0 | 0 | 0 | 100 | F | 10 | 0 | 90 | 0 | - |
| Apple | *Malus* | CPS | Ukraine | | 1,500 | 2 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Apple | *Malus* | ICABOL | Italy | ○ | 1,447 | 1 | 0 | 0 | 0 | 100 | F | 0 | 30 | 0 | 70 | - |
| Apple | *Malus* | DRESIOF | Germany | ○ | 1,269 | 1 | 0 | 0 | 0 | 100 | F | 19 | 3 | 63 | 15 | - |
| Apple | *Malus* | CRAGXPP | Belgium | | 1,175 | 1 | 0 | 0 | 0 | 100 | F | 0 | 100 | 0 | 0 | - |
| Apple | *Malus* | CPS | Ukraine | | 1,150 | 1 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Apple | *Malus* | IPK-I | Germany | ○ | 1,142 | 1 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Apple | *Malus* | FRUITRE | Italy | ○ | 1,104 | 1 | 0 | 0 | 0 | 100 | F | 0 | 8 | 92 | 0 | - |
| Apple | *Malus* | HOLOVOU | Czech Rep. | ○ | 1,037 | 1 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Apple | *Malus* | Others | | | 30,272 | 31 | | | | 100 | | | | | 100 | - |
| **Apple** | ***Malus*** | **Total** | | | **97,534** | **100** | **0** | **1** | **0** | **99** | | **0** | **5** | **49** | **46** | **-** |
| *Prunus* | *Prunus* | DFBBAL | Sweden | ○ | 6,815 | 11 | 0 | 0 | 0 | 100 | F | 22 | 1 | 4 | 73 | - |
| *Prunus* | *Prunus* | UNMIHT | USA | | 6,100 | 9 | 0 | 0 | 0 | 100 | | 0 | 0 | 98 | 2 | - |
| *Prunus* | *Prunus* | BG-Nikita | Ukraine | | 4,787 | 7 | 0 | 0 | 0 | 100 | F | 0 | 0 | 75 | 25 | - |
| *Prunus* | *Prunus* | ICPP | Romania | | 3,229 | 5 | 0 | 0 | 0 | 100 | F | 0 | 0 | 100 | 0 | - |
| *Prunus* | *Prunus* | HORFLOR | Italy | ○ | 2,170 | 3 | 0 | 0 | 0 | 100 | F | 0 | 52 | 48 | 0 | - |
| *Prunus* | *Prunus* | CPS | Ukraine | | 2,022 | 3 | 0 | 0 | 0 | 100 | | 0 | 0 | 35 | 65 | - |
| *Prunus* | *Prunus* | CPS | Ukraine | | 2,000 | 3 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| *Prunus* | *Prunus* | VIR | Russia | ◑ | 1,892 | 3 | 0 | 0 | 0 | 100 | | 0 | 0 | 100 | 0 | - |
| *Prunus* | *Prunus* | ICABOL | Italy | ○ | 1,329 | 2 | 0 | 0 | 0 | 100 | F | 0 | 11 | 60 | 29 | - |
| *Prunus* | *Prunus* | Others | | | 34,110 | 53 | | | | 100 | | | | | 100 | - |
| ***Prunus*** | ***Prunus*** | **Total** | | | **64,454** | **100** | **0** | **0** | **0** | **100** | **F** | **2** | **2** | **27** | **68** | **-** |
| Grape | *Vitis* | INRA/ENSA-M | France | ○ | 5,158 | 11 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | EERMJEF | Spain | ○ | 3,185 | 7 | 0 | 0 | 0 | 100 | F | 0 | 70 | 30 | 0 | - |
| Grape | *Vitis* | INRA-Bord-VI | France | ○ | 2,720 | 6 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | ENCINCM | Spain | ○ | 2,605 | 6 | 0 | 0 | 0 | 100 | F | 0 | 44 | 56 | 0 | - |
| Grape | *Vitis* | IGB-Geilweil | Germany | ○ | 2,235 | 5 | 100 | 0 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | CR-DAV | USA | | 2,130 | 5 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | KRSAC | Canada | | 2,035 | 4 | 0 | 0 | 0 | 100 | F | 0 | 0 | 100 | 0 | - |
| Grape | *Vitis* | INRA-Bord-FO | France | ○ | 2,000 | 4 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | BRAT | Slovakia | | 1,900 | 4 | 0 | 0 | 0 | 100 | F | 0 | 1 | 99 | 0 | - |
| Grape | *Vitis* | INRA-Colmar | France | ○ | 1,837 | 4 | 0 | 0 | 0 | 100 | F | 0 | 0 | 100 | 0 | - |
| Grape | *Vitis* | CNPUV | Brazil | | 1,315 | 3 | 0 | 0 | 0 | 100 | F | 0 | 0 | 100 | 0 | - |
| Grape | *Vitis* | UHFI-RIVE | Hungary | | 1,135 | 2 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | CENARGEN | Brazil | ◑ | 1,098 | 2 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | UHFITRIN | Hungary | | 1,043 | 2 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Grape | *Vitis* | Others | | | 16,423 | 35 | | | | 100 | | | | | 100 | - |
| **Grape** | ***Vitis*** | | | | **46,819** | **100** | **5** | **0** | **0** | **95** | | **0** | **7** | **20** | **72** | **-** |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | Accessions | | Storage facilities (%) | | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | No. | % | LT | MT | ST | Others | | ws | lr/oc | ac/bl | Oth | % |
| **Fruits** | | | | | | | | | | | | | | | |
| Cantaloupe | *Cucumis* | VIR | Russia | 4,510 | 33 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Cantaloupe | *Cucumis* | NC-7 | USA | 3,532 | 26 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Cantaloupe | *Cucumis* | NSSL | USA | 1,441 | 11 | 100 | 0 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Cantaloupe | *Cucumis* | GEVES-Angers | France | 1,399 | 10 | 0 | 0 | 0 | 100 | | 0 | 19 | 81 | 0 | - |
| Cantaloupe | *Cucumis* | BGUPV | Spain | 1,091 | | 90 | 10 | 0 | 0 | | 0 | 10 | 0 | 90 | - |
| Cantaloupe | *Cucumis* | SPII | Iran | 1,034 | | 0 | 100 | 0 | 0 | | 0 | 18 | 0 | 82 | - |
| Cantaloupe | *Cucumis* | Others | | 471 | | | | | 100 | | | | | 100 | - |
| **Cantaloupe** | ***Cucumis*** | **Total** | | **13,478** | **100** | **18** | **68** | **0** | **14** | | **0** | **4** | **8** | **87** | **-** |
| Lemon | *Citrus* | CIRAD | France | 1,100 | 18 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Lemon | *Citrus* | Others | | 5,074 | 82 | | | | 100 | | | | | 100 | - |
| **Lemon** | ***Citrus*** | **Total** | | **6,174** | **100** | **0** | **0** | **0** | **100** | | **0** | **0** | **0** | **100** | **-** |
| Nut | *Anacardium* | IPB-UPLB | Philippines | 1,302 | 23 | 0 | 0 | 0 | 100 | F | 100 | 0 | 0 | 0 | - |
| Nut | *Anacardium* | Others | | 4,268 | 77 | | | | 100 | | | | | 100 | - |
| **Nut** | ***Anacardium*** | **Total** | | **5,570** | **100** | **0** | **0** | **0** | **100** | | **23** | **0** | **0** | **77** | **-** |
| Nut | *Corylus* | FRUITUR | Italy | 1,500 | 65 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Nut | *Corylus* | Others | | 803 | 35 | | | | 100 | | | | | 100 | - |
| **Nut** | ***Corylus*** | **Total** | | **2,303** | **100** | **0** | **0** | **0** | **100** | | **0** | **0** | **0** | **100** | **-** |
| Peach palm | *Bactris* | UCR-MAG | Costa Rica | 1,100 | 36 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Peach palm | *Bactris* | Others | | 1,914 | 64 | | | | 100 | | | | | 100 | - |
| **Peach palm** | ***Bactris*** | **Total** | | **3,014** | **100** | **0** | **0** | **0** | **100** | | **0** | **0** | **0** | **100** | **-** |
| Pear | *Pyrus* | VIR | Russia | 1,140 | 100 | 0 | 0 | 0 | 100 | | 0 | 0 | 100 | 0 | - |
| Pear | *Pyrus* | Others | | | | | | | 100 | | | | | 100 | - |
| **Pear** | ***Pyrus*** | **Total** | | **1,140** | **100** | **0** | **0** | **0** | **100** | | **0** | **0** | **100** | **0** | **-** |
| *Ribes* | *Ribes* | DFBBAL | Sweden | 7,151 | 55 | 0 | 0 | 0 | 100 | F | 1 | 1 | 6 | 92 | - |
| *Ribes* | *Ribes* | Others | | 5,883 | 45 | | | | 100 | | | | | 100 | - |
| ***Ribes*** | ***Ribes*** | **Total** | | **13,034** | **100** | **0** | **0** | **0** | **100** | | **1** | **1** | **3** | **96** | **-** |
| Rose | *Rosa* | DFBBAL | Sweden | 6,032 | 60 | 0 | 0 | 0 | 100 | F | 10 | 1 | 24 | 65 | - |
| Rose | *Rosa* | CBN-Gap | Belgium | 1,650 | 17 | 0 | 0 | 0 | 100 | F | 0 | 0 | 0 | 100 | - |
| Rose | *Rosa* | GEVES-Sophia | France | 1,200 | 12 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Rose | *Rosa* | Others | | 1,090 | 11 | | | | 100 | | | | | 100 | - |
| ***Rose*** | ***Rosa*** | **Total** | | **9,972** | **100** | **0** | **0** | **0** | **100** | | **6** | **1** | **15** | **79** | **-** |
| *Sorbus* | *Sorbus* | DFBBAL | Sweden | 1,682 | 85 | 0 | 0 | 0 | 100 | F | 3 | 1 | 36 | 60 | - |
| *Sorbus* | *Sorbus* | Others | | 297 | 15 | | | | 100 | | | | | 100 | - |
| ***Sorbus*** | ***Sorbus*** | **Total** | | **1,979** | **100** | **0** | **0** | **0** | **100** | | **3** | **1** | **31** | **66** | **-** |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | | ws | lr/oc | ac/bl | Oth | % |
| **Fruits** | | | | | | | | | | | | | | | | |
| Strawberry | *Fragaria* | DFBBAL | Sweden | ○ | 9,346 | 69 | 0 | 0 | 0 | 100 | F | 0 | 0 | 24 | 76 | - |
| Strawberry | *Fragaria* | CCG-PGRC | Canada | ◑ | 1,682 | 13 | 0 | 0 | 0 | 100 | | 94 | 0 | | 0 | - |
| Strawberry | *Fragaria* | Others | | | 2,420 | 18 | | | | 100 | | | | | 100 | - |
| **Strawberry** | ***Fragaria*** | **Total** | | | **13,448** | **100** | **0** | | **0** | **100** | | **12** | **0** | **17** | **71** | **-** |
| **Oil crops** | | | | | | | | | | | | | | | | |
| Sunflower | *Helianthus* | ICPCPT | Romania | | 5,790 | 20 | 0 | 0 | 100 | 0 | | 0 | 4 | 95 | 1 | - |
| Sunflower | *Helianthus* | IFVCNS | Yugoslavia | | 5,450 | 19 | 0 | 8 | 0 | 92 | F | 8 | 0 | 92 | 0 | - |
| Sunflower | *Helianthus* | NC-7 | USA | ◑ | 3,122 | 11 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sunflower | *Helianthus* | VIR | Russia | ◑ | 2,994 | 10 | 0 | 0 | 0 | 100 | | 15 | 0 | 85 | 0 | - |
| Sunflower | *Helianthus* | INRA-Clermon | France | ○ | 2,500 | 9 | 0 | 0 | 0 | 100 | | 0 | 32 | 68 | 0 | - |
| Sunflower | *Helianthus* | RCA | Hungary | ◑ | 1,416 | 5 | 0 | 0 | 0 | 100 | V | 0 | 0 | 0 | 100 | - |
| Sunflower | *Helianthus* | SCA-LOVRIN | Romania | | 1,125 | 4 | 0 | 0 | 100 | 0 | | 0 | 2 | 98 | 0 | - |
| Sunflower | *Helianthus* | Others | | | 6,949 | 24 | | | | 100 | | | | | 100 | - |
| **Sunflower** | ***Helianthus*** | **Total** | | | **29,346** | **100** | **0** | **1** | **24** | **75** | | **3** | **4** | **54** | **39** | **-** |
| Palm | *Elaeis* | INERA | D.R. Congo | | 17,631 | 83 | 0 | 0 | 0 | 100 | | 1 | 0 | 99 | 0 | - |
| Palm | *Elaeis* | PORIM | Malaysia | | 1,467 | 7 | 0 | 0 | 0 | 100 | | 100 | 0 | 0 | 0 | - |
| Palm | *Elaeis* | Others | | | 2,108 | 10 | | | | 100 | | | | | 100 | - |
| **Palm** | ***Elaeis*** | **Total** | | | **21,206** | **100** | **0** | **0** | **0** | **100** | | **8** | **0** | **82** | **10** | **-** |
| Sesame | *Sesamum* | REHOUOT | Israel | | 3,000 | 17 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | ICGR-CAAS | China | ◑ | 2,138 | 12 | 100 | 0 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | NBPGR-Akola | India | ◑ | 1,723 | 10 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | INIA-Iguala | Mexico | ◑ | 1,600 | 9 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | INIFAP | Mexico | | 1,500 | 8 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | CENIAP | Venezuela | | 1,328 | 7 | 0 | 0 | 100 | 0 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | GBK | Kenya | | 1,239 | 7 | 100 | 0 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | VIR | Russia | ◑ | 1,146 | 6 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | S-9 | USA | ◑ | 1,077 | 6 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Sesame | *Sesamum* | Others | | | 2,980 | 17 | | | | 100 | | | | | 100 | - |
| **Sesame** | ***Sesamum*** | **Total** | | | **17,731** | **100** | **19** | **17** | **7** | **56** | | **0** | **0** | **0** | **100** | **-** |
| Safflower | *Carthamus* | INIA-Iguala | Mexico | ◑ | 1,550 | 19 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Safflower | *Carthamus* | INIFAP | Mexico | | 1,500 | 18 | 0 | 100 | 0 | 0 | | 0 | 0 | 0 | 100 | - |
| Safflower | *Carthamus* | NBPGR | India | ◑ | 1,050 | 13 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Safflower | *Carthamus* | Others | | | 4,174 | 50 | | | | 100 | | | | | 100 | - |
| **Safflower** | ***Carthamus*** | **Total** | | | **8,274** | **100** | **0** | **37** | **0** | **63** | | **0** | **0** | **0** | **100** | **-** |
| Castor seed | *Ricinus* | VIR | Russia | ◑ | 1,100 | 37 | 0 | 0 | 0 | 100 | | 0 | 0 | 0 | 100 | - |
| Castor seed | *Ricinus* | Others | | | 1,895 | 63 | | | | 100 | | | | | 100 | - |
| **Castor seed** | ***Ricinus*** | **Total** | | | **2,995** | **100** | **0** | **0** | **0** | **100** | | **0** | **0** | **0** | **100** | **-** |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Oil Crops** | | | | | | | | | | | | | | | |
| Other oils | Various | PD-OILSEED | India | ○ | 15,629 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Other oils | Various | Others | | | 0 | 0 | | | | 100 | | | | 100 | - |
| **Other oils** | **Various** | **Total** | | | **15,629** | **100** | **0** | **0** | **0** | **100** | **0** | **0** | **0** | **100** | **-** |
| **Sugar crops** | | | | | | | | | | | | | | | |
| Beet | *Beta* | | Germany | ○ | 2,207 | 9 | 0 | 100 | 0 | 0 | 63 | 12 | 21 | 4 | - |
| Beet | *Beta* | CGN/ CPRO-DLO | Netherlands | ◑ | 2,207 | 9 | 0 | 100 | 0 | 0 | 63 | 12 | 21 | 4 | - |
| Beet | *Beta* | BGRC | Germany | ○ | 2,167 | 9 | 0 | 100 | 0 | 0 | 65 | 12 | 22 | 1 | - |
| Beet | *Beta* | IFVCNS | Yugoslavia | | 2,140 | 9 | 0 | 100 | 0 | 0 | 0 | 7 | 93 | 0 | - |
| Beet | *Beta* | INRA-Dijon | France | ○ | 1,630 | 7 | 0 | 31 | 0 | 69 | 11 | 31 | 58 | 0 | - |
| Beet | *Beta* | VIR | Russia | ◑ | 1,589 | 7 | 0 | 0 | 0 | 100 | 0 | 0 | | 100 | - |
| Beet | *Beta* | IPK | Germany | ○ | 1,575 | 7 | 18 | 82 | 0 | 0 | 0 | 0 | | 100 | - |
| Beet | *Beta* | MENNES | France | ○ | 1,200 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | | 100 | - |
| Beet | *Beta* | NNAES | Japan | ○ | 1,164 | 5 | 0 | 0 | 0 | 100 | 2 | 0 | 98 | 0 | - |
| Beet | *Beta* | NC-7 | USA | ◑ | 1,056 | 4 | 0 | 100 | 0 | 0 | 100 | 0 | | 0 | - |
| Beet | *Beta* | Others | | | 7,150 | 30 | | | | 100 | | | | 100 | - |
| **Beet** | ***Beta*** | **Total** | | | **24,085** | **100** | **1** | **48** | **0** | **51** | **23** | **6** | **23** | **49** | **-** |
| Sugar cane | *Saccharum* | CENARGEN | Brazil | ◑ | 4,565 | 20 | 0 | 0 | 0 | 100 F | 0 | 0 | | 100 | - |
| Sugar cane | *Saccharum* | SBI | India | ○ | 3,979 | 18 | 0 | 0 | 0 | 100 F | 0 | 0 | | 100 | - |
| Sugar cane | *Saccharum* | WICSCBS | Barbados | | 2,567 | 11 | 0 | 0 | 0 | 100 F | 0 | 0 | | 100 | - |
| Sugar cane | *Saccharum* | CR-MIA | USA | ◑ | 2,038 | 9 | 0 | 0 | 0 | 100 | 0 | 0 | | 100 | - |
| Sugar cane | *Saccharum* | Romana | Dominican Rep. | | 1,965 | 9 | 0 | 0 | 0 | 100 F | 0 | 0 | 97 | 3 | - |
| Sugar cane | *Saccharum* | EEC-INICA | Cuba | | 1,400 | 6 | 0 | 0 | 0 | 100 F | 0 | 0 | | 100 | - |
| Sugar cane | *Saccharum* | Others | | | 4,950 | 22 | | | | 100 | | | | 100 | - |
| **Sugar cane** | ***Saccharum*** | **Total** | | | **21,464** | **100** | **0** | **0** | **0** | **100** | **0** | **0** | **14** | **86** | **-** |
| **Forage crops** | | | | | | | | | | | | | | | |
| Legumes | Various | CIAT | CGIAR | ● | 20,829 | 31 | 50 | 50 | 0 | 0 | 100 | 0 | 0 | | 0 |
| Legumes | Various | ATFGRC | Australia | | 15,000 | 22 | 20 | 80 | 0 | 0 | 100 | 0 | 0 | 0 | 30 |
| Legumes | Various | AGRESEARCH | New Zealand | | 13,000 | 19 | 0 | 100 | 0 | 0 | 40 | 6 | 54 | 0 | - |
| Legumes | Various | ICARDA | CGIAR | ● | 7,918 | 12 | 40 | 60 | 0 | 0 F/V* | 99 | 1 | 0 | 0 | 0 |
| Legumes | Various | ILRI | CGIAR | ● | 7,542 | 11 | 0 | 47 | 0 | 53 F | 97 | 0 | 3 | 0 | 74 |
| Legumes | Various | INIA-Iguala | Mexico | ◑ | 2,300 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Legumes | Various | Others | | | 87 | 0 | | | | 100 | | | | 100 | - |
| **Legumes** | **Various** | **Total** | | | **66,676** | **100** | **20** | **32** | **0** | **6** | **42** | **12** | **0** | **4** | **-** |
| Clover | *Trifolium* | AGRESEARCH | New Zealand | | 18,000 | 23 | 0 | 100 | 0 | 0 | 40 | 6 | 54 | 0 | - |
| Clover | *Trifolium* | WADA | Australia | | 11,500 | 15 | 80 | 0 | 20 | 0 | 100 | 0 | 0 | 0 | 80 |
| Clover | *Trifolium* | VIR | Russia | ○ | 5,131 | 7 | 0 | 10 | 0 | 90 | 0 | 0 | 0 | 100 | - |

> (continued) **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Forage crops** | | | | | | | | | | | | | | | |
| Clover | *Trifolium* | ICARDA | CGIAR | ● | 3,401 | 4 | | 60 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| Clover | *Trifolium* | AMGRC | Australia | | 2,500 | 3 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 100 |
| Clover | *Trifolium* | SIAEX | Spain | ○ | 2,434 | 3 | 0 | 100 | 0 | 0 | 93 | 0 | 7 | 0 | - |
| Clover | *Trifolium* | IPK-I | Germany | ○ | 2,173 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | NE-9 | USA | | 2,167 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | S-9 | USA | ◑ | 1,733 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | RCA | Hungary | ◑ | 1,479 | 2 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | INRA-Dijon | France | ● | 1,445 | 2 | 0 | 47 | 0 | 53 | 91 | 0 | 5 | 4 | 74 |
| Clover | *Trifolium* | USACLOVER | USA | | 1,273 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | TNAES | Japan | ○ | 1,070 | 1 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Clover | *Trifolium* | Others | | | 24,099 | 31 | | | | 100 | | | | 100 | - |
| **Clover** | ***Trifolium*** | **Total** | | | **78,405** | **100** | **15** | **33** | **3** | **46** | **33** | **1** | **13** | **50** | **-** |
| *Medicago* | *Medicago* | SARDI | Australia | | 20,000 | 38 | 90 | 10 | 0 | 0 | 98 | 2 | 0 | 0 | 40 |
| *Medicago* | *Medicago* | ICARDA | CGIAR | ● | 8,456 | 16 | 40 | 60 | 0 | 0 | 98 | 1 | 1 | 0 | 0 |
| *Medicago* | *Medicago* | AGRESEARCH | New Zealand | | 2,000 | | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Medicago* | *Medicago* | ARC-Libya | Libya | | 1,927 | | 0 | 0 | 0 | 100 | 100 | 0 | 0 | 0 | - |
| *Medicago* | *Medicago* | RCA | Hungary | ◑ | 1,292 | | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Medicago* | *Medicago* | AMFO | France | ○ | 1,140 | | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Medicago* | *Medicago* | Others | | | 17,949 | 34 | | | | 100 | | | | 100 | - |
| ***Medicago*** | ***Medicago*** | **Total** | | | **52,764** | **100** | **6** | **12** | **0** | **40** | **19** | **0** | **0** | **39** | **-** |
| *Vicia* | *Vicia* | ICARDA | CGIAR | ● | 5,353 | 20 | 40 | 60 | 0 | 0 | 98 | 2 | 0 | 0 | 0 |
| *Vicia* | *Vicia* | VIR | Russia | ◑ | 3,138 | 12 | 0 | 10 | 0 | 90 | 0 | 0 | 0 | 100 | - |
| *Vicia* | *Vicia* | CRF | Spain | ○ | 2,264 | | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| *Vicia* | *Vicia* | SOUTA | UK | ○ | 1,834 | | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| *Vicia* | *Vicia* | IPGR | Bulgaria | ○ | 1,541 | | 0 | 33 | 0 | 67 | 0 | 0 | 0 | 100 | - |
| *Vicia* | *Vicia* | Others | | | 12,114 | 46 | | | | 100 | | | | 100 | - |
| ***Vicia*** | ***Vicia*** | **Total** | | | **26,244** | **100** | **15** | **24** | **0** | **61** | **27** | **0** | **0** | **73** | **-** |
| Pea | *Lathyrus* | IBEAS | France | ○ | 3,627 | 27 | 0 | 100 | 0 | 0 | 9 | 0 | 0 | 91 | - |
| Pea | *Lathyrus* | ICARDA | CGIAR | ● | 1,682 | 13 | 40 | 60 | 0 | 0 | 99 | 1 | 0 | 0 | 0 |
| Pea | *Lathyrus* | Others | | | 7,944 | 60 | 0 | 100 | 0 | 0 | 99 | 1 | 0 | 0 | |
| **Pea** | ***Lathyrus*** | **Total** | | | **13,253** | **100** | **5** | **95** | **0** | **0** | **74** | **1** | **0** | **25** | **-** |
| Trefoil | *Lotus* | AGRESEARCH | New Zealand | | 1,800 | 50 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Trefoil | *Lotus* | Others | | | 1,836 | 50 | | | | 100 | | | | 100 | - |
| **Trefoil** | ***Lotus*** | **Total** | | | **3,636** | **100** | **0** | **50** | **0** | **50** | **0** | **0** | **0** | **100** | **-** |
| Grasses | Various | AGRESEARCH | New Zealand | | 13,000 | 33 | 0 | 100 | 0 | 0 | 40 | 6 | 54 | 0 | - |
| Grasses | Various | ATFGRC | Australia | | 8,000 | 21 | 20 | 80 | 0 | 0 | 100 | 0 | 0 | 0 | 30 |
| Grasses | Various | KNAES | Japan | ○ | 4,849 | 12 | 0 | 0 | 0 | 100 F | 100 | 0 | 0 | 0 | - |
| Grasses | Various | ILRI | CGIAR | ● | 3,539 | 9 | 0 | 47 | 0 | 53 F | 93 | 0 | 7 | 0 | 74 |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Forage crops** | | | | | | | | | | | | | | | |
| Grasses | Various | CIAT | CGIAR | ● | 3,080 | 8 | 0 | 0 | 0 | 100 | 100 | 0 | 0 | 0 | 0 |
| Grasses | Various | RCA | Hungary | ◑ | 2,039 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | Various | INIA-Iguala | Mexico | ◑ | 1,200 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Grasses | Various | IHAR | Poland | | 1,200 | 3 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | Various | INIFAP | Mexico | | 1,130 | 3 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Grasses | Various | Others | | | 854 | 2 | | | | 100 | | | | 100 | - |
| **Grasses** | **Various** | **Total** | | | **38,891** | **100** | **0** | **10** | **0** | **23** | **16** | **0** | **1** | **17** | **-** |
| Grasses | *Dactylis* | BYDG | Poland | | 6,010 | 22 | 0 | 100 | 0 | 0 | 0 | 97 | 1 | 2 | - |
| Grasses | *Dactylis* | IHAR | Poland | | 5,440 | 20 | 0 | 100 | 0 | 0 | 0 | 98 | 2 | 0 | - |
| Grasses | *Dactylis* | NGRI | Japan | ○ | 2,684 | 10 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | *Dactylis* | NARC-Japan | Japan | ○ | 2,000 | 7 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | *Dactylis* | WPBS-IGER | UK | ○ | 1,209 | 4 | 0 | 100 | 0 | 0 | 62 | 2 | 17 | 19 | - |
| Grasses | *Dactylis* | VIR | Russia | ◑ | 1,072 | 4 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | *Dactylis* | NNAES | Japan | ○ | 1,055 | 4 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Grasses | *Dactylis* | W-6 | USA | ◑ | 1,044 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Grasses | *Dactylis* | Others | | | 6,594 | 24 | | | | 100 | | | | 100 | - |
| Grasses | *Lolium* | AGRESEARCH | New Zealand | | 18,000 | 47 | 0 | 100 | 0 | 0 | 6 | 0 | 94 | | |
| Grasses | *Lolium* | BYDG | Poland | | 2,176 | 6 | 0 | 100 | 0 | 0 | 0 | 96 | 2 | 2 | - |
| Grasses | *Lolium* | IPK-I | Germany | ○ | 1,534 | 4 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Grasses | *Lolium* | BGRC | Germany | ○ | 1,104 | 3 | 0 | 100 | 0 | 0 | 5 | 48 | 47 | 0 | - |
| Grasses | *Lolium* | Others | | | 15,335 | 40 | | | | 100 | | | | 100 | - |
| **Grasses** | ***Lolium*** | **Total** | | | **38,149** | **100** | **0** | **60** | **0** | **40** | **3** | **7** | **46** | **44** | **-** |
| Fescue | *Festuca* | IHAR | Poland | | 4,484 | 19 | 0 | 100 | 0 | 0 | 0 | 95 | 5 | 0 | - |
| Fescue | *Festuca* | KNAES | Japan | ○ | 2,844 | 12 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Fescue | *Festuca* | LRS | Canada | | 1,195 | 5 | 0 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Fescue | *Festuca* | AGRESEARCH | New Zealand | | 1,100 | 5 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Fescue | *Festuca* | NNAES | Japan | ○ | 1,052 | 4 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Fescue | *Festuca* | Others | | | 13,050 | 55 | | | | 100 | | | | 100 | - |
| **Fescue** | ***Festuca*** | **Total** | | | **23,725** | **100** | **0** | **29** | **0** | **71** | **5** | **18** | **1** | **76** | **-** |
| Millet | *Panicum* | KNAES | Japan | ○ | 2,813 | 13 | 0 | 0 | 0 | 100 F | 0 | 0 | 0 | 100 | - |
| Millet | *Panicum* | UES | Ukraine | | 2,600 | 12 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Millet | *Panicum* | ICRISAT | CGIAR | ● | 1,232 | 6 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 4 |
| Millet | *Panicum* | Univ-AgrSc | India | ○ | 1,121 | 5 | 0 | 0 | 100 | 0 | 0 | 51 | 0 | 49 | - |
| Millet | *Panicum* | Others | | | 13,417 | 63 | | | | 100 | | | | 100 | - |
| **Millet** | ***Panicum*** | **Total** | | | **21,183** | **100** | **1** | **5** | **5** | **89** | **0** | **3** | **0** | **97** | **-** |
| Grasses | *Poa* | BYDG | Poland | | 2,329 | 29 | 0 | 100 | 0 | 0 | 0 | 96 | 3 | 1 | - |
| Grasses | *Poa* | Others | | | 5,593 | 71 | | | | 100 | | | | 100 | - |

> *(continued)* **Germplasm accessions by crop**

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Forage crops** | | | | | | | | | | | | | | | |
| **Grasses** | | **Total** | | | **7,922** | **100** | **0** | **29** | **0** | **71** | **0** | **28** | **1** | **71** | **-** |
| Grasses | *Bromus* | AGRESEARCH | New Zealand | | 2,220 | 52 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Grasses | *Bromus* | Others | | | 2,067 | 48 | | | | 100 | | | | 100 | - |
| **Grasses** | ***Bromus*** | **Total** | | | **4,287** | **100** | **0** | **52** | **0** | **48** | **0** | **0** | **0** | **100** | **-** |
| Grasses | *Cenchrus* | GBK | Kenya | | 1,119 | 52 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | - |
| Grasses | *Cenchrus* | Others | | | 1,013 | 48 | | | | 100 | | | | 100 | - |
| **Grasses** | ***Cenchrus*** | **Total** | | | **2,132** | **100** | **52** | **0** | **0** | **48** | **52** | **0** | **0** | **48** | **-** |
| Grasses | *Andropogon* | NSSL | USA | ◑ | 1,066 | 84 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Grasses | *Andropogon* | Others | | | 197 | 16 | | | | 100 | | | | 100 | - |
| **Grasses** | ***Andropogon*** | **Total** | | | **1,263** | **100** | **0** | **0** | **0** | **100** | **0** | **0** | **0** | **100** | **-** |
| *Phleum* | *Phleum* | IHAR | Poland | | 2,536 | 28 | 0 | 100 | 0 | 0 | 0 | 96 | 4 | 0 | - |
| *Phleum* | *Phleum* | BYDG | Poland | | 2,468 | 27 | 0 | 100 | 0 | 0 | 0 | 98 | 2 | 0 | - |
| *Phleum* | *Phleum* | Others | | | 4,123 | 45 | | | | 100 | | | | 100 | - |
| ***Phleum*** | ***Phleum*** | **Total** | | | **9,127** | **100** | **0** | **55** | **0** | **45** | **0** | **53** | **2** | **45** | **-** |
| Rye | *Elymus* | SVALOF | Sweden | ○ | 2,198 | 82 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Rye | *Elymus* | Others | | | 467 | 18 | | | | 100 | | | | 100 | - |
| **Rye** | ***Elymus*** | **Total** | | | **2,665** | **100** | **0** | **0** | **0** | **100** | **0** | **0** | **0** | **100** | **-** |
| **Fibre crops** | | | | | | | | | | | | | | | |
| Cotton | *Gossypium* | CICR | India | ○ | 5,249 | 11 | 0 | 0 | 0 | 100 | 0 | 0 | 73 | 27 | - |
| Cotton | *Gossypium* | PAU | India | ○ | 3,905 | 8 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | IRCT-CIRAD | France | ○ | 3,562 | 7 | 40 | 5 | 0 | 55 | 14 | 42 | 2 | 42 | - |
| Cotton | *Gossypium* | CIRAD | France | ○ | 3,000 | 6 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | CIHNP | India | ○ | 2,518 | 5 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | SOY-S | USA | ◑ | 1,587 | 3 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | - |
| Cotton | *Gossypium* | ICGR-CAAS | China | ◑ | 1,285 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | MAU | India | ○ | 1,200 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | HAU | India | ○ | 1,070 | 2 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cotton | *Gossypium* | Others | | | 25,513 | 52 | | | | 100 | | | | 100 | - |
| **Cotton** | ***Gossypium*** | **Total** | | | **48,889** | **100** | **6** | **0** | **0** | **94** | **1** | **6** | **8** | **85** | **-** |
| Flax | *Linum* | VIR | Russia | ◑ | 5,240 | 21 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Flax | *Linum* | PGRC-E | Ethiopia | ◑ | 3,110 | 13 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | - |
| Flax | *Linum* | USAFLAX | USA | ◑ | 2,659 | 11 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Flax | *Linum* | ICPCPT | Romania | | 2,500 | 10 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 100 | - |
| Flax | *Linum* | SUMPERK | Czech Rep. | ○ | 1,921 | 8 | 0 | 0 | 100 | 0 | 0 | 27 | 73 | 0 | - |
| Flax | *Linum* | Others | | | 9,449 | 38 | | | | 100 | | | | 100 | - |
| **Flax** | ***Linum*** | **Total** | | | **24,879** | **100** | **0** | **34** | **18** | **49** | **0** | **2** | **6** | **92** | **-** |

## > *(continued)* Germplasm accessions by crop

| Crop | | Genebank | | | Accessions | | Storage facilities (%) | | | | Type of accession (%) | | | | Dupl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grouping | Genus | Institute | Country | | No. | % | LT | MT | ST | Others | ws | lr/oc | ac/bl | Oth | % |
| **Fibre crops** | | | | | | | | | | | | | | | |
| Jute | *Corchorus* | BJRI | Bangladesh | ◑ | 1,564 | 62 | 100 | 0 | 0 | 0 | 0 | 81 | 14 | 5 | - |
| Jute | *Corchorus* | Others | | | 970 | 38 | | | | 100 | | | | 100 | - |
| **Jute** | ***Corchorus*** | **Total** | | | **2,534** | **100** | **62** | **0** | **0** | **38** | **0** | **50** | **9** | **41** | **-** |
| **Beverage crops** | | | | | | | | | | | | | | | |
| Cocoa | *Theobroma* | CENARGEN | Brazil | ◑ | 2,286 | 24 | 0 | 0 | 0 | F | 0 | 0 | 0 | 100 | - |
| Cocoa | *Theobroma* | CRI-ICG | Trinidad and Tobago | | 2,030 | 22 | 0 | 0 | 0 | 100 F | 7 | 0 | 0 | 93 | - |
| Cocoa | *Theobroma* | CENIAP | Venezuela | | 1,583 | 17 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| Cocoa | *Theobroma* | Others | | | 3,465 | 37 | | | | 100 | | | | 100 | - |
| **Cocoa** | ***Theobroma*** | **Total** | | | **9,364** | **100** | **0** | **0** | **0** | **100** | **2** | **0** | **0** | **98** | **-** |
| Coffee | *Coffea* | CIRAD | France | | 3,800 | 18 | 0 | 0 | 0 | 100 | 0 | 0 | 100 | 0 | - |
| Coffee | *Coffea* | IRCC-CIRAD | Côte d'Ivoire | | 6,560 | 31 | 0 | 0 | 0 | 100 | 87 | 0 | 2 | 11 | - |
| Coffee | *Coffea* | IRA | Cameroon | | 1,552 | 7 | 0 | 0 | 0 | 100 | 24 | 0 | 38 | 38 | - |
| Coffee | *Coffea* | CATIE | Costa Rica | ◑ | 1,415 | 7 | 0 | 0 | 0 | 100 | 6 | 0 | 0 | 94 | - |
| Coffee | *Coffea* | JRS | Ethiopia | ○ | 1,284 | 6 | 0 | 0 | 0 | 100 | 0 | 0 | 7 | 93 | - |
| Coffee | *Coffea* | Others | | | 6,476 | 31 | | | | 100 | | | | 100 | - |
| **Coffee** | ***Coffea*** | **Total** | | | **21,087** | **100** | **0** | **0** | **0** | **100** | **29** | **0** | **22** | **49** | **-** |
| Opium | *Papaver* | AARI | Turkey | | 1,899 | 27 | 0 | 100 | 0 | | 0 | 0 | 0 | 100 | - |
| Opium | *Papaver* | RCA | Hungary | ◑ | 1,392 | 20 | 0 | 100 | 0 | | 0 | 0 | 0 | 100 | - |
| Opium | *Papaver* | Others | | | 3,702 | 53 | | | | 100 | | | | 100 | - |
| **Opium** | ***Papaver*** | **Total** | | | **6,993** | **100** | **0** | **47** | **0** | **53** | **0** | **0** | **0** | **100** | **-** |
| **Miscellaneous** | | | | | | | | | | | | | | | |
| *Arabidopsis* | *Arabidopsis* | INRA-Versail | France | ○ | 16,000 | 59 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Arabidopsis* | *Arabidopsis* | NASC | UK | ○ | 8,000 | 30 | 100 | 0 | 0 | 0 | 9 | 0 | 91 | 0 | - |
| *Arabidopsis* | *Arabidopsis* | IPK-I | Germany | ○ | 3,000 | 11 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | - |
| *Arabidopsis* | *Arabidopsis* | Others | | | 4 | 0 | | | | 100 | | | | 100 | - |
| ***Arabidopsis*** | ***Arabidopsis*** | **Total** | | | **27,004** | **100** | **30** | **0** | **0** | **70** | **3** | **0** | **27** | **70** | **-** |

*: 1% of the collection is under cryopreservation.

**: Australian rape-brassica collections are considered as oil crops, not vegetables.

*Main source*: WIEWS database. Some modifications made according to CGIAR-SGRP Genebank Reviews and National Genebank reports.

| ACRONYMS | Institutes |
|---|---|
| AARI | Plant Genetic Resources Dept. Aegean Agricultural Research Institute, Izmir, Turkey |
| AD-KU | University of Kasetsart, Faculty of Agriculture Department of Agronomy, Bangkok, Thailand |
| AGRESEARCH | New Zealand Forage Germplasm Centr. Agriculture Research Institute Ltd, Palmerston North, New Zealand |
| AICSIP | All India Coordinated Sorghum Improvement Project, Rajandranagar, India |
| AMFO | GIE Amelioration Fourragere, Provins, France |
| AMGRC | Australian Medicago Genetic Resources Centre, Adelaide, Australia |
| ARC-Libya | Agricultural Research Centre, Tripoli, Libyan Arab Jamahiriya |
| ARC-Sudan | Plant Breeding Section Agricultural Research Corporation, Wad Medani, Sudan |
| ARI | Agricultural Research Institute, Mogadishu, Somalia |
| ARI | Agricultural Research Institute Plant Genetic Res. and Herbarium, Nicosia, Cyprus |
| ARS | Department of Agricultural Res. Sebele Agric. Research Station, Gaborone, Botswana |
| ASP | American Sorghum Project, Tihama, Yemen |
| ATFCC | Australian Temperate Field Crops Collection, Horsham, Victoria, Australia |
| ATFGRC | Australian Tropical Forage Genetic Resources Cenre, Queensland, Australia |
| AVRDC | Asian Vegetable Research and Development Centre, Taiwan, China |
| BAZ | Institute for Resistance Genetics, Fed. Centre for Breeding Research, Grenbach, Germany |
| BCA | Bunda College of Agriculture, Lilongwe, Malawi |
| BERGAMO | Istituto Sperimentale per la Cerealicoltura, Bergamo, Italy |
| BG-Nikita | Nikita Botanical Garden, Yalta, Ukraine |
| BGRC | Institut fuer Pflanzenbau Bundesforschungsanst. fur Landwirt, Braunschweig, Germany |
| BGUPV | Genebank of the Polytechnical University of Valencia, Valencia, Spain |
| BJRI | Bangladesh Jute Research Institute, Dhaka, Bangladesh |
| BPGV-DRAEDM | Banco Português de Germoplasma Vegetal (BPGV), Braga, Portugal |

| | |
|---|---|
| **BRAT** | Research Institute for Viticulture and Enology, Bratislava, Slovakia |
| **BRRI** | Bangladesh Rice Research Institute, Dhaka, Bangladesh |
| **BYDG** | Botanical Garden of Plant Breeding and Acclimatization Institute, Bydgoszcz, Poland |
| **Campbell** | Campbell Institute for Agr. Res. Campbell Soup Company, Camden, New Jersey, United States |
| **CATIE** | Centro Agrónomico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica |
| **CBICAU** | Crop Breeding Institute, Harare, Zimbabwe |
| **CBN-Gap** | Conservatoire Botanique National Alpin de Gap-Charance, Genape, Belgium |
| **CCG-PGRC** | Canadian Clonal Genebank - PGRC Agriculture and Agri-Food Canada, Trenton, Ontario, Canada |
| **CENARGEN** | Centro Nacional de Pesquisa de Recursos Genéticos e Biotecnologia, Brasilia, Brazil |
| **CENIAP** | Centro Nacional de Investigaciones Agropecuarias-FONAIAP, Maracay, Venezuela |
| **CERI** | National Agricultural Research Foundation Cereal Institute, Thermi, Thessaloniki, Greece |
| **CGN/CPRO-DLO** | Centre for Genetic Resources, the Netherlands (CGN), Wageningen, Netherlands |
| **CHRCRD** | Cantebury Agriculture and Science Centre DSIR, Crop Research Div., Lincoln, New Zealand |
| **CIAT** | Centro Internacional de Agricultura Tropical Cali, Colombia |
| **CICR** | Central Institute for Cotton Research, Panjori Farm, Nagpur, Maharashtra, India |
| **CIDACOR** | Centro de Investig. y Desarrollo Agrario Alameda del Obispo, Cordoba, Spain |
| **CIF** | Centro de Investigaciones en Forajes, Panama, Panama |
| **CIFAP-CEL** | Centro de Investigaciones Forest. y Agropecuarias - INIFAP, Celaya, Gto. Mexico |
| **CIFAP-MEX** | Centro de Investigaciones Forest. y Agropecuarias, Prog. de Res. Gen., Chapingo, Mexico |
| **CIHNP** | Central Institute of Horticulture for Northern Plains, Lucknow, Uttar Pradesh, India |
| **CIMMYT** | Centro Internacional de Mejoram. del maíz y del trigo, Mexico City, Mexico |
| **CIP** | Centro Internacional de la Papa, Lima, Peru |
| **CIRAD** | Centre de Coop. Int. en Recherche Agronomique pour le Developpement, Montpellier, France |

| | |
|---|---|
| **CIRN-INTA** | Centro de Invest. de Recursos Nac. Instituto de Recursos Biológicos, Castelar, Prov. de Buenos Aires, Argentina |
| **CNPAF** | Rice and Beans National Research Centre - EMBRAPA, Goiana, Goias, Brazil |
| **CNPH** | Horticultural National Research Centre - EMBRAPA, Brasilia, Brazil |
| **CNPMF** | Cassava and Tropical Fruit Crops National Research Centre - EMBRAPA, Cruz das Almas, Bahia, Brazil |
| **CNPMS** | Corn and Sorghum National Research Centre - EMBRAPA, Sete Lagdas, Minas Gerais, Brazil |
| **CNPSO** | Centro Nacional de Pesquisa de Soja, Londrina, Parana, Brazil |
| **CNPT** | Wheat National Research Centre - EMBRAPA, Passo Fundo, Rio Grande do Sul, Brazil |
| **CNPUV** | National Grape and Wine Research Centre, Bento Gonacalves, Rs, Brazil |
| **CPBBD** | Central Plant Breeding and Biotech. Division Nat. Agric. Res. Council, Khumaltar, Nepal |
| **CPRI** | Central Potato Research Institute, Shimla, Himachal Pradesh, India |
| **CPS** | Crimean Pomological Station, Sevastopol, Ukraine |
| **CR-DAV** | Nat. Clonal Germplasm Repository Department of Pomology, Davis, California, United States |
| **CR-MIA** | Subtropical Horticultural Research Unit - USDA, Miami, Florida, United States |
| **CRAGXPP** | Centre de Rech. Agron. de l'Etat Station de Phytopathogie, Gembloux, Belgium |
| **CRF** | Centro de Recursos Fitogenéticos, Alcalá de Henares, Madrid, Spain |
| **CRI** | Corn Research Institute, Ha Tay, Viet Nam |
| **CRI-ICG** | Cocoa Research Unit Int. Cocoa Genebank, Univ. of the West Indies, St. Augustine, Trinidad and Tobago |
| **CRIA** | Central Research Institute for Agriculture, Bogor, Indonesia |
| **CRIFC** | Bogor Research Institute for Food Crops, Bogor, Indonesia |
| **CRRI** | Central Rice Research Institute, Cuttack, Orissa, India |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organization |
| **DAFS** | Department of Agriculture and Fisheries for Scotland, Edinburgh, United Kingdom |
| **DAR** | Dept. of Agricultural Research Ministry of Agriculture, Gaborone, Botswana |
| **DENAREF** | Dept. Nacional de Recursos Fitogenéticos Est. Exp. Santa Catalina, Quito, Ecuador |

| | |
|---|---|
| **DF-GUAV** | Diputación Foral de Guipuzcoa Unidad Area Vegetal, San Sebastián, Spain |
| **DFBBAL** | Dept. of Hort. Fruit Breeding Balsgard, Swed. Univ. of Agr. Sci., Kristianstad, Sweden |
| **DG** | Division of Genetics ICAR, New Delhi, India |
| **DGABGHZ** | Banco de Germoplasma de Horticolas, Zaragoza, Spain |
| **DH-CARS** | Division of Horticulture Central Agric. Res. Station, Reduit, Mauritius |
| **DHSNYST** | Horticultural Sciences Department New York State Agric. Experiment Stat., Geneva, New York, United States |
| **DRA** | Department de Recherches Agronom. de la Republique Malgache, Antananarivo, Madagascar |
| **DRESIOF** | Genbank Obst Inst. fur Pflanzen- genetik und Kulturpflanzenforsch., Dresden, Germany |
| **DTCP-CSIRO** | Division of Tropical Crops and Pasture - CSIRO Queensland, Australia |
| **EAPZ** | Escuela Agrícola Panamericana El Zamorano, Valle del Zamorano, Tegucigalpa, Honduras |
| **EEC-INICA** | Estación Experimental de la Cana, Jovellanos, Matanzas, Cuba |
| **EERMJEF** | Estación Experimental Rancho de la Merced, Jeréz de la Frontera, Cadiz, Spain |
| **EMBRAPA** | Empresa Brasileira de Pesquisa Agropecuária, Brasilia D. F., Brazil |
| **ENCINCM** | Subdirección General de Investig. Agraria, Finca El Encin, Alcalá de Henares, Madrid, Spain |
| **ENMP-Cereais** | Departamento de Cereais Est. Nacional Melhoramento Plantas, Elvas, Portugal |
| **ENMP-Past** | Sector de Proteaginosas Dept. de Past., Forragense Proteaginosas, Elvas, Portugal |
| **FCRI** | Field Crops Research Institute Agricultural Research Centre (ARC), Giza, Egypt |
| **FONAIAP-EE.P** | Estación Experimental Portuguesa, Araure, Venezuela |
| **FRUITRE** | Experimental Institute for Fruit Crops, Trento, Italy |
| **FRUITUR** | Department of Pomology University of Turin, Turin, Italy |
| **GBK** | Crop Plant Genetic Resources Centr. Genebank of Kenya, Kikuyu, Muguga, Kenya |
| **GCRI** | Small Grain Centre - Grain Crops Res. Inst. Dep. Agric. and Water Supply, Bethlehem, South Africa |
| **GEVES-Angers** | Unite experimentale d'Angers GEVES, Brien, France |
| **GEVES-Sophia** | Unite experimentale de Sophia-Antipolis GEVES, Biot, France |

| | |
|---|---|
| **GEVES-UE** | Unite experimentale du Magneraud GEVES, Surgeres, France |
| **GGB** | Greek Gene Bank Agric. Res. Centre of Macedonia and Thracé, Thermi, Thessaloniki, Greece |
| **GMO** | Germplasm Management Office, Yongdang, Republic of Korea |
| **GOTIPP** | Inst. of Agronomy and Plant Breed. Georg-August-University Goettingen, Goettingen, Germany |
| **HAAS** | Soybean Research Institute, Heilongjiang Academy of Agric. Sc., Harbin, Heilongjiang Prov., China |
| **HAES** | Highlands Agricultural Experiment Station, Kainantu, Ehp, Papua New Guinea |
| **HAIFA** | Institute of Evolution Haifa University, Haifa, Israel |
| **HAS-ARI** | Agricultural Research Institute Hungarian Academy of Sciences, Martonvasar, Hungary |
| **HAU** | Haryana Agriculture University, Hisar, Haryana, India |
| **HBROD** | Potato Research Institute Havlickuv Brod Ltd., Havlickuv Brod, Czech Republic |
| **HNA** | Hokkaido National Agricultural Experiment Station, Shimamatsu, Eniwa, Japan |
| **HOLOVOU** | SEMPRA a.s. Research Inst. for Fruit Growing and Breeding, Holovousy, Czech Republic |
| **HORFLOR** | Department of Horticulture, University of Florence, Florence, Italy |
| **HRI** | Horticulture Research International, Wellesbourne, United Kingdom |
| **IAB** | Institute of Agroecology and Biotechnology, Kiev, Ukraine |
| **IARI** | Indian Agricultural Research Institute, Sirsa, India |
| **IARI-Maize** | All India Coordinated Maize Improvement Project, Pusa Campus, New Delhi, India |
| **IBEAS** | IBEAS Universite de Pau, Pau, France |
| **IBKNA** | Ibusuki Branch Kyushu National Agricultural Experiment Station, Kagoshima, Japan |
| **IBTA-EE.PATA** | Estación Experimental Patacamaya, Inst. Boliviano de Tec. Agropec., La Paz, Bolivia |
| **IBTA-TORALAP** | IBTA Estación Experimental Toralapa, Cochabamba, Bolivia |
| **ICA-NAL** | Instituto Colombiano Agropecuario, Santafé de Bogotá, Colombia |
| **ICA-Region 1** | ICA Centro de Investigación Tibaitata, El Dorado, Santafé de Bogotá, Colombia |

| | |
|---|---|
| **ICA-Region 4** | Banco Colombiano de Maíz Centro de Investigación Tulio Ospina, Medellín, Antioquia, Colombia |
| **ICA-Region 5** | ICA, Centro de Investigaciones Palmira, Palmira Valle, Colombia |
| **ICABOL** | Dipartimento di Coltivazioni Arboree, Università di Bologna, Bologna, Italy |
| **ICAR** | Indian Council of Agricultural Research, New Delhi, India |
| **ICARDA** | Internat. Centre for Agricultural Research in the Dry Areas, Beirut, Lebanon |
| **ICBC-CAAS** | Institute of Crop Breeding and Cult. CAAS, Beijing, China |
| **ICFR** | New Zealand Institute for Crop and Food Research Ltd, Christchurch, New Zealand |
| **ICGR-CAAS** | Inst. of Crop Germplasm Resources CAAS, Beijing, China |
| **ICPCPT** | Genetic Resources Dep. Research Inst. for Cereals and Ind. Crops, Fundulea, Judetul Calarasi, Romania |
| **ICPP** | Fruit Research Institute, Pitesti-Maracineni, Judetul Arges, Romania |
| **ICR-SAAS** | Institute of Crop Research Sichuan Academy of Agric. Sciences, Chengdu, Sichuan Province, China |
| **ICRISAT** | International Crop Research Inst. for the Semi-Arid Tropics, Patancheru, Andra Pradesh, India |
| **IDG** | Istituto del Germoplasma, Bari, Italy |
| **IFC-GAAS** | Institute of Field Crops Guangdong Academy of Agric. Sc., Guangzhou, Guangdong Province, China |
| **IFVCNS** | Institute for Field and Vegetable Crops Faculty of Agriculture, Novi Sad, Yugoslavia |
| **IGB** | Israel Gene Bank for Agricultural Crops Agric. Research Org., Bet Davan, Israel |
| **IGB-Geilweil** | Institute for Grapevine Breeding Geilweilerhof, Siebeldingen, Germany |
| **IGFRI** | Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India |
| **IH** | Institute for Horticulture, Chernovtsy, Ukraine |
| **IHAR** | Plant Breeding and Acclimatization Institute, Radzikow, Poland |
| **IIC-JAAS** | Institute of Industrial Crops Jiangsu Academy of Agric. Sciences, Nanjing, Xiaolingwei, Jiangsu Prov., China |
| **IIHR** | Indian Institute of Horticultural Research, Bangalore, Karnataka, India |

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| **IITA** | International Institute of Tropical Agriculture, Ibadan, Nigeria |
| **ILCA** | International Livestock Centre for Africa, Addis Ababa, Ethiopia |
| **ILCA-Kenya** | Kenyan Rangelands Programme Int. Livestock Centre for Africa, Nairobi, Kenya |
| **ILRI** | International Livestock Research Institute, Addis Ababa, Ethiopia |
| **INERA** | Institut National pour l'Etude et la Recherche Agronomique, Kisangani, Democratic Republic of Congo |
| **INIA** | Unidad de Recursos Genéticos Centro de Investig. Agric. Bajío, Celaya, Guanajuato, Mexico |
| **INIA-GNorte** | Centro de Investigaciones Agrícolas del Golfo Norte INIA, Mexico |
| **INIA-Iguala** | Instituto Nacional de Investig. Agrícolas, Estación de Iguala, Iguala, Mexico |
| **INIAP** | Estación Experimental Pichilingue, Quevedo, Ecuador |
| **INIAP-EE.BOL** | INIAP Estación Experimental Boliche, Guayaquil, Ecuador |
| **INIFAP** | Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico D.F., Mexico |
| **INIFAP-BG** | Banco de Germoplasma Instituto Nac. Inv. Forest., Agric. y Pecuar, Mexico D.F., Mexico |
| **INIFAT** | Inst. de Invest. Fundamentales en Agric. Trop. Banco de Germoplasma, Santiago de Las Vegas, Habana, Cuba |
| **INRA-ANGERS** | Station d'Amelioration des Especes Fruitieres et Ornementales, Beaucouze Cedex, France |
| **INRA-Avign-M** | Station d'Amelioration des Plantes Maraicheres - INRA Avignon Montfavet Cedex, France |
| **INRA-Bord-FO** | Recherches Forestieres, Pierroton, Cestas, France |
| **INRA-Bord-VI** | Station de Recherches en Viticulture INRA, Villenave D'Ornon Cedex, France |
| **INRA-Clermon** | Station d'Amelioration des Plantes, Clermont-Ferrand Cedex, France |
| **INRA-Colmar** | Station de Recherches Vigne et Vin Laboratoire de Viticulture INRA, Colmar Cedex, France |
| **INRA-Dijon** | Station de Genetique et d'Amelioration des Plantes INRA, Genlis, France |
| **INRA-Montp** | Genetics and Plant Breeding Station ESRA-INRA SGAP, Mauguio, France |

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| **INRA-Poitou** | Station d'Amelioration des Plantes Fourrageres INRA, Lusignan, France |
| **INRA-Rennes** | Station d'Amelioration des Plantes INRA, Le Rheu, France |
| **INRA-RENNES** | Station d'Amelioration de la Pomme de Terre et Plantes à Bulbes INRA, Ploudaniel, France |
| **INRA-Versail** | Station de Genetique/Amelioration des Plantes INRA, Versailles Cedex, France |
| **INRA/ENSA-M** | Station de Recherches Viticoles INRA, Marseilla Plage, France |
| **INTA** | Estación Experimental Agropecuaria Alto Valle de Río Negro, Argentina |
| **INTA-EEA-PER** | Estación Experiment. Agropecuaria Pergamino, Pergamino, Buenos Aires, Argentina |
| **INTA-EEAMANF** | Estación Experimental Agropecuaria Manfredi, Manfredi, Córdoba, Argentina |
| **INTABAL** | Estación Experimental Agropecuaria Balcarce, Balcarce, Buenos Aires, Argentina |
| **INTAMAN** | Instituto Nacional de Tecnología Agropecuaria, Buenos Aires, Argentina |
| **INTSOY** | International Soybean Program University of Illinois, Urbana, Illinois, United States |
| **IOCR-CAAS** | Institute of Oil Crops Research CAAS, Wuhan, China |
| **IOP-JAAS** | Institute of Pomology Jilin Academy of Agricultural Sciences, Gongzhuling, Jilin Province, China |
| **IORR-JAAS** | Institute of Rice Research, Jiangxi Academy of Agric. Sciences, China |
| **IPA** | Pernambuco Agricultural Research Company, Serra Talhada, Pernambuco, Brazil |
| **IPB-UPLB** | Institute of Plant Breeding College of Agriculture - UPLB, College, Laguna, Philippines |
| **IPGR** | K Malkov Institute of Plant Introduction and Genetic Resources, Sadovo, District Plovdiv, Bulgaria |
| **IPK** | Institute of Plant Genetics andCrop Plant Research, Gaterleben, Germany |
| **IPK-I** | Genebank Institute of Plant Genetics and Crop Plant Research, Gaterleben, Germany |
| **IPK-Rye** | Rye and Triticale Collection Inst. Plant Genet. Crop Plant Res., Guelzow, Guestrow, Germany |
| **IPK-Taxo** | Inst. Plant Gen. and Crop Plant Res. Department of Taxonomy, Gatersleben, Germany |
| **IPRBON** | Potato Research Institute, Zonin, near Koszalin, Poland |

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| **IPSR** | John Innes Centre Norwich Research Park, Norwich, Norfolk, United Kingdom |
| **IR-1** | Inter-Regional Potato Introd. Stat. Peninsula Experiment Station - USDA, Sturgeon Bay, Wisconsin, United States |
| **IRA** | Institut de la Recherche Agronomique, Yaounde, Cameroon |
| **IRCC-CIRAD** | Institut de Recherches du Café et du Cacao et autres Plantes Stim., Abidjan, Côte d'Ivoire |
| **IRCT-CIRAD** | CIRAD-CA Departement des cultures annuelles, Montpellier Cedex, France |
| **IRRI** | International Rice Research Institute, Manila, Philippines |
| **IRRI-Cambod** | IRRI Cambodia Project, Bangkok, Thailand |
| **ISAR** | Institut des Sciences Agronomiques du Rwanda, Butare, Rwanda |
| **IVCP** | Maritsa Institute of Vegetable Crops Plovdiv, Bulgaria |
| **JRS** | Jimma Research Station, Jimma, Ethiopia |
| **KL-TNA** | Kariwano Laboratory Tohoku Nat. Agricultural Experiment Station, Nishi-Senboku, Japan |
| **KNAES** | Kyushu National Agricultural Experiment Station, Kikuchi-Gun, Kumamoto-Ken, Japan |
| **KROME** | Agricultural Research Institute Kromeriz Co. Ltd, Kromeriz, Czech Republic |
| **KRSAC** | Kentville Research Station Agriculture Canada, Nova Scotia, Canada |
| **KYOPGI** | Plant Germplasm Institute Fac. of Agriculture Kyoto University, Kyoto, Japan |
| **LBN** | National Biological Institute, Bogor, Indonesia |
| **LIMAGRAIN** | LIMAGRAIN Genetics, Riom Cedex, France |
| **LRS** | Lethbridge Research Station Agriculture Canada, Lethbridge, Alberta, Canada |
| **LRSAC** | Lacombe Research Station Agriculture Canada, Alberta, Canada |
| **LUBLIN** | Inst. Genetics and Plant Breeding University of Agriculture, Lublin, Poland |
| **MACS** | Maharashtra Association for the Cultivation of Science, Pune, Maharashtra, India |
| **MAU** | Marathwada Agriculture University, Parhbani, Maharashtra, India |
| **MENNES** | Institut de Recherche Mennessoy, Anizy-Le-Chateau, France |
| **MOALD** | Northern National Centre for Phaseolus Bean Research, Moshi, United Republic of Tanzania |
| **MRIZP** | Zemun Polje Maize Research Institute, Belgrade, Zemun, Yugoslavia |

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| **MRRI** | Maize and Rice Research Institute, Shkodra, Albania |
| **MRS** | Msekera Research Station, Chipata, Zambia |
| **NARC** | National Agric. Research Station, Kitale, Kenya |
| **NARC-Japan** | National Agricultural Research Center, Tsukuba-Shi, Ibarakiken, Japan |
| **NARC-Paki** | National Agricultural Research Centre, Islamabad, Pakistan |
| **NARC-Thika** | National Agricultural Research Station Thika, Thika, Kenya |
| **NARS** | National Dryland Farming Research Station, Machakos, Kenya |
| **NASC** | Nottingham Arabidopsis Stock Centr. Dpt. Life Sci. Univ. of Nottingham, Nottingham, United Kingdom |
| **NBPGR** | National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi, India |
| **NBPGR-Akola** | NBPGR Regional Station Akola, Akola, Maharashtra, India |
| **NC-7** | North Central Regional Plant Introduction Station - USDA-ARS, Ames, Iowa, United States |
| **NCARS** | North Carolina Agric. Res. Service North Carolina State University, Raleigh, North Carolina, United States |
| **NCRI** | National Cereals Research Institute, Ibadan, Nigeria |
| **NCSTUNCS** | Crop Science Department N. Carolina State University, Raleigh, North Carolina, United States |
| **NE-9** | Northeastern Regional Plant Introd. Station, NY St. Agric. Exp. Station, Geneva, New York, United States |
| **NFC** | National Fruit Collection Wye College - Univ. of London, Faversham, Kent, United Kingdom |
| **NGB** | Nordic Gene Bank, Alnarp, Sweden |
| **NGRI** | National Grassland Research Institute, Nasu-Gun, Tochigiken, Japan |
| **NIAR** | Department of Genetic Resources I Nat. Inst. of Agrobio. Resources, Tsukuba-Gun, Ibarakiken, Japan |
| **NNAES** | Hokkaido National Agricultural Experiment Station, Sapporoshi, Japan |
| **NPGRL** | National Plant Genetic Resources Laboratory - IPB/UPLB, Laguna, Philippines |
| **NRC-Sorghum** | National Research Centre (Sorghum), Hyderabad, India |
| **NRCG** | National Research Centre for Groundnut, Junagadh, Gujarat, India |
| **NRCS-Soy** | National Research Centre for Soybean, Indore, Madhya Pradesh, India |
| **NRSSL** | The National Rice Seed Storage Laboratory for Genetic Resources, Prathum Thani, Thailand |

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| **NSGC** | National Small Grain Collection - USDA-ARS, Aberdeen, Idaho, United States |
| **NSSL** | National Seed Storage Laboratory - USDA-ARS, Colorado State University, Fort Collins, Colorado, United States |
| **NYSAES** | New York State Agricultural Exp. Station Cornell University, Geneva, New York, United States |
| **ORSEM** | ORSEM S.A., Annoeullin, France |
| **ORSTOM** | Office de La Recherche Scient. Et Technique d'Outre Mer (ORSTOM), Abidjan, Côte d'Ivoire |
| **ORSTOM-Montp** | Lab. Ress. Genetiques et Amelior. des Plantes Tropicales ORSTOM, Montpellier, France |
| **PAIRUMANI** | Centro Fitotécnico y Ecogenético de Pairumani (Fundación I. Patino), Cochabamba, Bolivia |
| **PAN** | Botanical Garden of the Polish Academy of Sciences, Warsaw, Poland |
| **PAU** | Punjab Agricultural University, Ludhiana, Punjab, India |
| **PC-Groundnut** | Project Coordinator (Groundnut), Yunagadh, India |
| **PC-RAPE&MU** | All India Coord. Research Proj. on Rape and Mustard, Hary. Agric. Univ., Hisar, Haryana, India |
| **PD-OILSEED** | Directorate of Oilseeds Research - ICAR, Hyderabad, Andhra Pradesh, India |
| **PD-WHEAT** | All Indian Coordinated Wheat Programme - IARI, New Delhi, India |
| **PGQC-USA** | National Plant Germplasm Quarantine Laboratory - USDA-ARS, Glenn Dale, Maryland, United States |
| **PGRC** | Plant Gene Resources of Canada Central Exper. Farm Agric. Canada, Ottawa, Ontario, Canada |
| **PGRC-E** | Plant Genetic Resources Centre, Addis Ababa, Ethiopia |
| **PGRC-India** | Plant Genetic Resources Centre - ICAR, New Delhi, India |
| **PGRI-NARC** | Plant Genetic Resources Institute National Agricultural Res. Centre, Islamabad, Pakistan |
| **PGRU** | Plant Genetic Resources Unit Crop Improv. Div., Ministry of Agriculture, Kabul, Afghanistan |
| **PLC** | Div. of Plant and Liquor Control Dep. of Agri. Econ. and Marketing, Pretoria, South Africa |
| **PORIM** | Palm Oil Research Institute of Malaysia, Kuala Lampur, Malaysia |
| **RAC** | Station Federale de Recherches Agronomiques de Changins, Nyon, Switzerland |
| **RCA** | Institute for Agrobotany, Tapioszele, Hungary |

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| **REHOUOT** | Dept. of Field and Vegetable Crops, Hebrew University of Jerusalem, Rehovot, Israel |
| **RES-BangKhen** | Bang Khen Rice Experiment Station, Bangkok, Thailand |
| **RICP-GP** | Genebank Dept. Div. Genet. and Plant Breed. Res. Inst. Crop Production, Prague, Ruzyne, Czech Republic |
| **RICP-Prague** | Genebank Department RICP Prague Vegetable Section Olomouc, Holice, Czech Republic |
| **RIPP** | Research Institute of Plant Production, Piestany, Slovakia |
| **RNG** | Agricultural Botany, Plant Sc. Lab. School of Plant Sc., Univ. Reading, Reading, United Kingdom |
| **Romana** | Central Romana Corporation La Romana, Dominican Republic |
| **ROPTA** | Plant Breeding Station Ropta, Metslawier, Netherlands |
| **RRC** | Rice Research Centre - MARDI, Seberang,Perai, Malaysia |
| **RRI** | Cuu Long River Delta Rice Research Institute, Hangiang, Viet Nam |
| **S-9** | Southern Regional Plant Introduction Station - USDA-ARS, Griffin, Georgia, United States |
| **SAARI** | Serere Agriculture and Animal Prod. Research Institute, Serere, Uganda |
| **SARD** | Genetic Resources Unit Scientific Agriculture Research Directorate, Douma, Damascus Syrian Arab Republic |
| **SBI** | Sugarcane Breeding Institute, Coimbatore, Tamil Nadu, India |
| **SCA-LOVRIN** | Agricultural Research Station, Lovrin, Judetul Timis, Romania |
| **SCA-TURDA** | Agricultural Research Station, Turda, Judetul Cluj, Romania |
| **SCRI** | Scottish Crop Research Institute, Invergowrie, Dundee, United Kingdom |
| **SGIKG** | Small Grains Research Centre, Kragujevac, Federal Republic of Yugoslavia |
| **SHRWIAT** | Plant Breeding Station, Wiatrowo, Wagrowiec, Poland |
| **SIAEX** | Servicio de Investig. y Desarrollo Tecnológico de Extremadura, Badajoz, Spain |
| **SIAVA** | Servicio de Investigación Agraria, Valladolid, Spain |
| **SOAFD** | Scottish Agricultural Science Agency, Edinburgh, United Kingdom |
| **SOUTA** | School of Biological Sciences University of Southampton, Southampton, United Kingdom |
| **SOY** | All India Coordinated Res. Project on Soybean Govind Bal. Plant Univ., Pantnagar, Uttar Pradesh, India |
| **SOY-N** | Northern Soybean Germp. Collection - USDA-ARS, University of Illinois, Urbana, Illinois, United States |

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| **SOY-S** | Southern Soybean Collection - USDA-ARS, Delta Branch Exp. Stat., Stoneville, Massachusetts, United States |
| **SPII** | Nat. Genebank of Iran, Genetic Resources Division, Karaj, Islamic Republic of Iran |
| **SRCPS** | Coastal Plains Experiment Station USDA-ARS, Tifton, Georgia, United States |
| **SRI-FC** | Sukamandi Research Institute for Food Crops, Sukamandi, Indonesia |
| **SRI-JAAS** | Soybean Research Institute Jilin Academy of Agric. Sciences, Gongzhuling, Jilin Province, China |
| **SRSFAC** | Station de recherches de Ste-Foy Agriculture Canada, Canada |
| **Suceava-Gbk** | Genebank of Suceava, Romania |
| **SUMPERK** | AGRITEC Research, Breeding and Services Ltd, Sumperk, Czech Republic |
| **SVALOF** | Dept. of Plant Breeding Research Swedish Univ. of Agric. Sciences, Svalov, Sweden |
| **TAES** | Texas Agricultural Experiment Station Texas A&M University, College Station, Texas, United States |
| **TAMAWC** | Australian Winter Cereals Collec. Agricultural Research Centre, Tamworth, New South Wales, Australia |
| **TARI** | Taiwan Agricultural Research Institute, Wufeng, Taichung County, Taiwan Province of China |
| **TELAVUN** | Leiberman Germplasm Bank Inst. Cereal Crop Improvt., Tel-Aviv Univ., Tel-Aviv, Israel |
| **TISTR** | Thailand Institute of Scientific and Technological Research, Bangkok, Thailand |
| **TNAES** | Tohoku National Agricultural Experiment Station, Iwateken, Japan |
| **TSS** | Taiwan Seed Service, Provincial Dept. of Agriculture and Forestry, Taiwan Province of China |
| **UASD-DCP** | University of Agric. Sciences Department of Crop Production, Debrecen, Hungary |
| **UC-ICN** | Instituto de Ciencias Naturales Universidad Central, Quito, Ecuador |
| **UCDKNAE** | Upland Crop Division Kyushu Nat. Agricultural Experiment Station, Nishigoshi, Kumamoto, Japan |
| **UCR-MAG** | Banco de Germoplasma de Pejibaye UCR-MAG-CRBANA, Dep. de Biología, San José, Costa Rica |
| **UCRD** | Upland Crops Research Division Crop Experiment Station, Suweon, Republic of Korea |
| **UDLIRTA** | Instituto de Investigación y Tecnología Agroalimentarias Centro UdL-IRTA, Lleida, Spain |

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| **UES** | Ustimovskaya Experimental Station, Globino District, Poltava Region, Ukraine |
| **UHFI-RIVE** | University of Hort. and Food Ind. Res. Inst. for Vitic. and Enology, Kecskemet, Hungary |
| **UHFITRIN** | Transdanubian Res. Inst. Viticulture and Enology Univ. Hort. Food Ind., Pecs, Hungary |
| **UNA** | Programa de Investig. Hortalizas Universidad Nacional Agraria (UNA) La Molina, Lima, Peru |
| **UNA-L.MOLINA** | Universidad Nacional Agraria La Molina, La Molina, Lima, Peru |
| **Univ-Agric** | Plant Breeding/Seed Prod. Section Dept. of Agronomy Agricult. Univ., Tirana, Albania |
| **Univ-AgrSc** | All India Coordinated Minor Millet Project Univ. of Agric. Sciences, Bangalore, India |
| **Univ-Kaset** | National Corn and Sorghum Research Centre Kasetsart University, Nakhou Ratchasima, Thailand |
| **Univ-Kyushu** | Fac. of Agriculture Institute for Gene Resources, Kyushu University, Fukuoka-shi, Japan |
| **Univ-Laval** | Departement de phytologie Universite Laval, Quebec, Canada |
| **Univ-Nanjing** | Nanjing Agricultural University, China |
| **Univ-Punjab** | Department of Genetics Punjab Agricultural University, Ludhiana, India |
| **Univ-Tehran** | College of Agriculture, Tehran University, Tehran, Islamic Republic of Iran |
| **UNMIHT** | Horticulture Department Michigan State University, East Lansing, Michigan, United States |
| **UNSAA** | Universidad Nacional San Antonio Abad, Cuzco, Peru |
| **USACLOVER** | Clover Collection, Dep. of Agron. University of Kentucky, Lexington, Kentucki, United States |
| **USAFLAX** | Flax Collection - USDA-ARS, North Dakota State University, Fargo, North Dakota, United States |
| **USDA** | Mayaguez Institute of Tropical Agriculture - USDA, SEA-AR, Puerto Rico |
| **USVL** | US Vegetable Laboratory - USDA, SEA/AR, Charleston, South Carolina, United States |
| **UTAD** | Dept. de Genetica e Biotecnologia Univ. Tras-os-Montes e Alto Douro, Vila Real Codex, Portugal |
| **VEGTBUD** | Vegetable Crops Research Institute Station Budapest, Budapest, Hungary |
| **VIR** | N.I. Vavilov Research Institute of Plant Industry, St. Petersburg, Russian Federation |

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| **W-6** | Western Reg. Plant Introd. Station - USDA-ARS, Washington State Univ., Pullman, Washington, United States |
| **WADA** | Western Australian Department of Agriculture, South Perth, Western Australia, Australia |
| **WARDA** | West African Rice Development Association, Bouake, Côte d'Ivoire |
| **WICSCBS** | West Indies Central Sugar Cane Breeding Station, George, Barbados |
| **WPBS-IGER** | Welsh Plant Breeding Station Inst. of Grassland and Environ. Res., Aberystwyth, Dyfed, United Kingdom |
| **WRS** | Winnipeg Research Station Agriculture Canada, Manitoba, Winnipeg, Canada |
| **YIPB** | Yuriev Institute of Plant Breeding, Kharkiv, Ukraine |
| **ZEAINVENT** | ZEAINVENT s.c., Trnava, Slovakia |

# APPENDIX 3
# Regions of Diversity of Cultivated Plants

## INTRODUCTION

During the preparatory process for the International Technical Conference, Synthesis Reports were prepared on a subregional basis and a series of subregional meetings were held. The division of countries into subregions was based partly on the criterion of similar plant genetic diversity. The subregions thus identified generally coincided well with the megacentres of diversity of cultivated plants described by Zeven and Zhukovsky (1975) which were based on Vavilov's[1] centres of origin.[2] The following section lists the crops with major centres of diversity in each of the subregions.[3]

### 1. East Asian subregion

This subregion encompasses the East Asian Centre of Origin as identified by Vavilov, and more or less coincides with Zeven and Zhukovsky's **Chinese-Japanese area** which is a centre of origin or diversity for the following crops, among others:

- prosomillet, foxtail millet, naked oat, buckwheat, japonica rice;
- Chinese cabbage, radish, Chinese yam, soybean, adzuki bean, rhubarb;
- orange, litchi, apricot, peach, jujube, kiwi fruit;
- ginseng, bamboo, camphor, mulberry, tea, tung.

The Chinese-Japanese area is also an important secondary centre of diversity for crops such as:

- barley, sorghum, maize, wheat (bread), taro, sesame;
- melon, cucumber/gherkin, aubergine, *Brassica juncea* (vegetable, oilseeds and forage).

The western part of China is covered by Zeven and Zhukovsky's Central Asian area (Section 5 for a relevant list of crops).

## 2. Southeast Asia subregion

This area was called by Vavilov the Tropical Asian Centre of Origin and it corresponds with Zeven and Zhukovsky's **Indochinese-Indonesian centre** in all respects except for the inclusion by the latter of a small area of southern China. It is a centre of origin or diversity for the following crops, among others:

- rice;
- taro, yam, breadfruit, winged bean;
- carambola, durian, mangosteen, rambutan, banana, citrus;
- bamboo, lemon grass, nutmeg, clove, betelnut, sandalwood, ginger, cardamon;
- Manilla hemp, coconut, sago palm, sugar cane.

The Indochinese-Indonesian area is also an important secondary centre of diversity for crops such as:

- cassava, maize, sweet potato;
- mango, coffee, tea (*Camellia* spp.).

## 3. Pacific subregion

An Australian/Pacific centre was not described by Vavilov, but an **Australian centre** was marked out by Zhukovsky (1970) because of the domestication in the area of several plant species related to important crops and the use of wild species as breeding parents. Zhukovsky's Australian area is the centre of origin or diversity for the following species, among others:

- macadamia nut, *Nicotiana* spp.;
- eucalyptus.

As well as Australia, the Pacific subregion includes New Zealand, Papua New Guinea and the Pacific Islands. The following crops have a centre of origin or diversity in this subregion:

- Oceanic races of rice;
- fe'i banana, sugar cane, coconut;
- kava pepper, sago palm.

The Pacific area is also an important secondary centre of diversity for crops such as:

- banana and plantain, breadfruit.

## 4. South Asia subregion

This subregion was included by Vavilov in the Tropical South Asian Centre of Origin. It corresponds to Zeven and Zhukovsky's **Hindustani area** which includes all the countries in the South Asia subregion, as well as the eastern part of Pakistan. It is a centre of origin or diversity for the following crops, among others:

- rice, kodo millet, Indian dwarf wheat;
- black gram, green gram, rice bean;
- leaf mustard, cucumber/gherkin, luffa, rat-tailed radish, okra, aubergine, giant taro;
- jackfruit, banana, mango, sarson and toria (*Brassica rapa*);
- black pepper, turmeric, cardamon, ginger;
- sunn hemp, tree cotton, jute, bamboo, sugar cane.

The Hindustani area is also an important secondary centre of diversity for crops such as:

- maize, sorghum, finger millet, wheat (bread);
- cowpea, pigeon pea, chickpea, sesame;
- sweet pepper, pumpkin/squash;
- coconut, tea.

## 5. Central Asia subregion

This subregion was called by Vavilov the Southwestern Asian centre. It more or less corresponds to Zeven and Zhukovsky's **Central Asian area**, which includes part of western China and the eastern part of Iraq, and excludes the northern part of Kazakhstan. This region is a centre of origin or diversity for the following crops, among others:

- wheat (bread, club), buckwheat;
- onion, garlic, carrot;
- spinach, faba bean;

- almond, apple, plum, grape, mulberry (black), quince, walnut, pistachio;
- opium poppy, flax, safflower, tarragon.

The Central Asian area is also an important secondary centre of diversity for crops such as:

- rye, maize, barley;
- beet, melon, chickpea;
- cotton, peach, apricot.

Northern parts of Kazakhstan fall into Zeven and Zhukovsky's Euro-Siberian area (Section 13), and the eastern part of Pakistan falls into Zeven and Zhukovsky's Hindustani area (Section 4).

## 6. West Asia subregion

This subregion generally corresponds to Zeven and Zhukovsky's **Near Eastern area** which is based on Vavilov's Near East Centre of Origin, and also includes parts of the Syrian Arab Republic and Jordan, which overlap with the Mediterranean region, as well as Georgia, Armenia and the southern part of the Russian Federation. The following crops are among those that have a centre of origin or diversity in this area:

- wheat (einkorn, durum, bread, emmer);
- rye, barley;
- lentil, pea;
- lettuce;
- fig, pomegranate, almond, cherry, grape, hazelnut.

The Near Eastern area is also an important secondary centre of diversity for crops such as:

- maize;
- garlic, cucumber, chickpea, *Brassica* vegetables;
- coffee, flax.

The coastal parts of Turkey fall into the Mediterranean area of diversity (Section 7).

## 7. South and East Mediterranean subregion

Vavilov identified a Mediterranean Centre of Origin, and Zeven and Zhukovsky recognize a **Mediterranean area** which includes all the countries bordering the Mediterranean (except those parts of Turkey and the Syrian Arab Republic that fall in the Near East area). The ICPPGR subregion includes only those countries bordering the south and east Mediterranean coasts, with the exception of Turkey. The European Mediterranean countries are included in Section 13. The following crops are among those that have a centre of origin or diversity in the Mediterranean:

- barley, oats;
- *Beta vulgaris, Brassica* spp., artichoke, celery, rocket;
- fennel, cumin, mint, caper, crocus, lupin;
- carob, olive, grape, date-palm.

The Mediterranean area is also an important secondary centre of diversity for crops such as:

- wheat (durum), sorghum, maize;
- chickpea, pea, faba bean alfalfa;
- onion, garlic, chicory;
- orange, lemon.

## 8. East Africa subregion

In Africa, Vavilov identified only one centre of origin, the Abyssinian Centre of Origin, which was also recognized by Darlington and Porteres.[4] Zeven and Zhukovsky later recognized an **African centre**, which covers the whole of Africa south of the Mediterranean region. The following crops are among those that have a centre of origin or diversity in the Abyssinian area:

- sorghum, pearl millet, finger millet, tef, Abyssinian oats;
- *Brassica carinata*, pigeon pea, pea, Niger seed, cowpea, sesame, faba bean;
- enset, coffee (arabica);
- cotton, kenaf, castor oil, safflower.

The Abyssinian area is also an important secondary centre of diversity for crops such as:

- wheat, maize, barley;
- flax, lentil;
- banana.

## 9. Indian Ocean Islands subregion

These islands are not recognized as centres of origin or diversity by Vavilov or Zeven and Zhukovsky and few agricultural crops have centres of origin or diversity here. The exceptions include:

- coffee in Madagascar.

However, the islands are an important area of secondary diversity for crops such as:

- banana;
- sugar cane;
- rice.

## 10. West Africa subregion

This subregion encompasses one of the cradles of agriculture in Africa identified by Porteres. It falls within Zeven and Zhukovsky's **African area**, which covers the whole of Africa south of the Mediterranean region. Porteres' West African cradle of agriculture has been subdivided into the Senegambian "subcradle", the Central Niger "subcradle", the Benin "subcradle" and the Adamawa "subcradle". It is a centre of origin or diversity for the following crops, among others:

- fonio, African rice, pearl millet, sorghum;
- yam, cowpea, bambara groundnut;
- bottle gourd, melon;
- kola nut, oil-palm, date-palm.

West Africa is also an important secondary centre of diversity for crops such as:

- maize;
- cassava.

## 11. Central Africa subregion

This subregion includes Darlington's Central African region of origin, and falls within Zeven and Zhukovsky's **African area**. It is a centre of origin or diversity for the following crops, among others:

- sorghum;
- yam, cowpea;
- oil-palm, kenaf, coffee (robusta).

## 12. Southern Africa subregion

Although not specifically recognized as a region of origin/diversity, a number of agricultural crops are identified as having a centre of origin or diversity in Southern Africa. Those include:

- finger millet, pearl millet, sorghum;
- cowpea, melon, *Cucumis* spp.;
- Enset, tamarind, sorrel, cotton, kenaf.

Southern Africa is also an important secondary centre of diversity for crops such as:

- sesame, maize, *Phaseolus*, tobacco;
- *Citrullus* spp.

## 13. Europe Region (including Western and Eastern Europe subregions)

The Europe region was not recognized as a centre of origin by Vavilov; Darlington (1956) was the first to refer to Europe as a region of origin of crop plants. Zeven and Zhukovsky identify a **Europe-Siberian region** which does not include the Mediterranean countries. The following crops are those occurring north of the Mediterranean but most of the crops identified in the South and East Mediterranean subregion (Section 7), also occur in the southern European countries.

- oats, wheat (bread in Transcaucasia);
- *Beta vulgaris* vegetable and forage, radish;
- asparagus, endive, chicory, lettuce, marjoram;
- strawberry, gooseberry, blackcurrant;
- apple, pear, cherry;

- cannabis, hops,[5] pyrethrum, chestnut;
- forage species including *Lolium* spp., *Festuca* spp., *Trifolium* spp.

The Euro-Siberian region is also an important secondary centre of diversity for crops such as:

- wheat (club), sorghum, barley, rye;
- sunflower;
- lemon, orange.

## 14. South America subregion

This subregion includes all countries of South America and encompasses the Andean Centre of Origin, identified by Vavilov, and subcentres in Chile/Chiloe Islands and Paraguay/South Brazil. It also encompasses Zeven and Zhukovsky's megacentre of **South America**, which includes most of Argentina, as well as the Andean region. The following crops, among others, have a centre of diversity or origin in South America:

- amaranthus, quinoa;
- sweet potato, potato, cassava, *Xanthosoma* (tannia), cush-cush yam, Andean tubers;
- groundnut, yam bean, *Phaseolus* spp.;
- pumpkin/squash, *Capsicum* spp., tomato;
- pineapple, passion fruit, cherimoya, feijoa, strawberry;
- cashew, cocoa, coca;
- tobacco, rubber, cotton, arrowroot, quinine.

South America is also an important secondary centre of diversity for crops such as:

- maize.

## 15. Central America and Mexico subregion

This subregion was described by Vavilov as the Central American and South Mexican Centre of Origin while Zeven and Zhukovsky call it the **Central American and Mexico Centre**. It includes all the countries of the region and corresponds exactly to the subregion of Central America and Mexico. The following crops, among others, have a centre of diversity or origin in Central America:

- maize, amaranthus;
- sweet potato, cassava;
- *Phaseolus* spp., squash/pumpkin, sweet pepper/chilli;
- papaya, avocado, guava, pecan;
- upland cotton, sisal, marigold, vanilla.

## 16. Caribbean subregion

The Caribbean subregion is not included in Zeven and Zhukovsky's megacentres of plant diversity. Very few food crops have centres of origin and/or diversity in this region, but the following have been identified:

- West Indian cherry, hog plum, *Annona* spp.;
- allspice/pimento, arrowroot.

The Caribbean is also an important secondary centre of diversity for crops such as:

- maize, *Phaseolus*;
- passion fruit, papaya, avocado.

## 17. North America subregion

The United States Centre of Origin was first established by Darlington and Janaki Ammal (1945) and subsequently enlarged by Zhukovsky to include the whole of the United States as a **North American Centre**. The North American subregion includes Canada as well as the United States. The following crops have a centre of origin or diversity here:

- Jerusalem artichoke, tepary bean;
- sunflower;
- cranberry, blueberry, raspberry, blackberry;
- American plum, strawberry, pecan;
- forage grasses.

North America is also an important secondary centre of diversity for crops such as:

- maize;
- peach;
- hardy grape.

## Appendix 3 endnotes

1 Vavilov NI (1928) Geographische Genzentren unserer Kulturplfanzen. Int Kongr G Vererb Wiss (1927) Zindukt Abstramm-u Vererblehre Suppl 1:342-269; and Vavlov NI (1931) The problem of the origin of world agriculture in the light of the latest investigations. *Science at the crossroads*, p. 1-20. London. See also Harlan JR (1951) Anatomy of gene centres. *American Naturalist,* 85:97-103.

2 The criteria used in this appendix, and in general by scientists, in determining regions or centres of origin or of diversity, will not necessarily be consistent with how others employ those terms. Thus, the identification in this appendix of a region or centre of diversity for a particular crop may - or may not - be particularly helpful in trying to ascertain a country of origin as defined in the Convention on Biological Diversity, for example.

3 Based on Zeven AC and Zhukovsky PM (1975) *Dictionary of cultivated plants and their centres of diversity*. Centre for Agricultural Publishing and Documentation: Wageningen, Germany, 219 pp. Revised as Zeven AC and de Wet JMJ (1982) *Dictionary of cultivated plants and their regions of diversity*. Centre for Agricultural Publishing and Documentation, Wageningen, Germany.

4 Darlington CD and EK Janaki Ammal (1945) *Chromosome atlas of cultivated plants*. G Allen & Unwin Ltd, London, 347 pp. Darlington CD (1956) *Chromosone botany and the origins of cultivated plants*. Revised 2nd Ed. G Allen & Unwin Ltd, London, 231 pp. Porters R (1962) Berceaux primaires sur le continent africain. *Journal of African History*, 3:195-210.

5 Neve gives the origin of hops as Asia and of cannabis as Central Asia, but notes a long history of domestication and breeding in Europe employing "indigenous" materials. Neve RA (1976) in Simmons NW (ed.)"*Hops" in evolution of crop plants*. p. 208-211. Longman, London.