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THE THIRD REPORT ON THE STATE OF THE WORLD'S PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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Foreword

Our agrifood systems face mounting challenges in sustainably feeding a growing global population, while ensuring social-economic stability. These challenges are compounded by the increasing frequency and intensity of extreme weather events, biodiversity loss, water scarcity, land degradation, and man-made pressures. Together, these factors disrupt agrifood systems and slow progress in the fight against hunger, malnutrition, and poverty. Today, more than 3.1 billion people—over 40 percent of the global population—cannot afford a healthy diet, and while the agrifood sectors provide employment for many, they do not guarantee a stable income for all. Urgent and innovative solutions are needed to turn these complex challenges into important opportunities for changes.

The FAO Strategic Framework 2022–31 is driving this transformation by promoting more efficient, more inclusive, more resilient, and more sustainable agrifood systems. It is anchored in the vision of the Four Betters: better production, better nutrition, a better environment, and a better life—leaving no one behind. Given the constraints of depleting arable land and water resources, sustainable solutions must focus on producing more with less, while safeguarding biodiversity and strengthening resilience to the impacts of the climate crisis.

Plant genetic resources for food and agriculture (PGRFA) are at the heart of this transformation. They are essential for developing biotic and abiotic resilient crops and diverse varieties that enhance food security, food diversity and sustainable livelihoods. Agricultural biodiversity provides natural paths against pests, diseases and environmental stresses such as droughts and soil erosion, helping to build resilience in farming systems. PGRFA also hold deep cultural and agronomic significance, sustaining traditional farming practices, including those of rural smallholders and Indigenous Peoples.

Despite their critical importance, the diversity of PGRFA is under growing threat. Of the 6,000 plant species cultivated for agriculture, just nine crops—sugarcane, maize, rice, wheat, potatoes, soybeans, oil palm fruit, sugar beet, and cassava—accounted for over 60 percent of global crop production in recent years. Given that over 80 percent of the world's food comes from plants, protecting and sustainably using PGRFA is a cornerstone of agrifood system transformation. This requires a holistic approach that spans in situ conservation, on-farm management, genebank preservation, and the breeding of diverse, high-performing, and climate-resilient crops. Equally crucial is ensuring farmers' access to sufficient, affordable and high quality seeds and planting materials of diverse, locally adapted and market fovourable varieties, including farmers' cultivars and landraces.

The *Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* is a landmark assessment prepared under the aegis of FAO's Commission on Genetic Resources for Food and Agriculture, in collaboration with the International Treaty on Plant Genetic Resources for Food and Agriculture. Covering the period 2011–2022, it provides a comprehensive analysis of the global status and trends in PGRFA conservation and use. This report offers a strong evidence base for shaping policies and refining strategies, including the rolling Global Plan of Action for Plant Genetic Resources for Food and Agriculture.

This report is the result of a truly global effort, with contributions from 128 countries, 13 international research centers, and four regional centers. Advances in data collection and analysis have improved the quality and scope of the information presented, offering critical insights into the state of PGRFA and the steps needed to ensure their conservation and sustainable use.

I am confident that this Third Report will inform and support FAO's work in scaling up evidence-based policies and strategies, improving national-level implementation, and strengthening collaboration among all Members and partners. It will also guide governments in prioritizing and implementing policies that promote advanced, responsible, inclusive innovation in plants. Strengthening the conservation and sustainable use of PGRFA is not just an agricultural priority - it is a fundamental necessity for ensuring a more sustainable, resilient, and food-secure future for all.

QU Dongyu
FAO Director-General

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The publication of *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoW3), prepared under the auspices of the Commission on Genetic Resources for Food and Agriculture (Commission) of the Food and Agriculture Organization of the United Nations (FAO), is the result of the collective efforts of a wide spectrum of stakeholders from around the world who are committed to the conservation and sustainable use of plant genetic resources for food and agriculture (PGRFA). The invaluable contributions of significant amounts of time and considerable depths and breadths of expertise and experience by these many individuals, who are too numerous to be mentioned individually, are gratefully acknowledged. This multi-year endeavour would not have been possible without the substantial contributions provided by many governments and institutions. The generous financial support provided by the governments of Canada, the Kingdom of the Netherlands, Norway and Spain are also acknowledged with gratitude.

The main source of information for the preparation of the SoW3 were the reports on the implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (GPA2) and on the Indicator 2.5.1.a of the United Nations Sustainable Development Goals on *ex situ* conservation of PGRFA. These country reports were coordinated by National Focal Points officially appointed for this purpose by their respective governments. FAO wishes to acknowledge and thank all the National Focal Points for their painstaking efforts in coordinating national stakeholders, assembling data and making those available to FAO.

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The SoW3 was prepared by a core team under the coordination of Stefano Diulgheroff and Bonnie Furman, and which included Arshiya Noorani and Chikelu Mba, all from FAO's Plant Production and Protection Division (NSP). Ndeye Ndack Diop, Wilson Hugo and Shawn McGuire, also of NSP, provided valuable contributions. Irene Hoffmann, Dan Leskien, Manoela Pessoa de Miranda, Dafydd Pilling and Suzanne Redfern, from the Secretariat of the Commission, along with Francisco López, Mario Marino, Marco Marsella, Kent Nnadozie and Álvaro Toledo of the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture also contributed immensely to the entire process. The significant contributions of Michael Halewood, Muhabbat Turdieva and Isabel López Noriega of the Alliance of Bioversity International and CIAT; and those of Peter Giovannini, Luigi Guarino and Matija Obreza of the Global Crop Diversity Trust, are also greatly appreciated. The continuous support and encouragement provided by the current and former Directors of FAO's NSP, Yurdi Yasmi and Jingyuan Xia, respectively, were invaluable throughout the process.

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Chapter 1 – Introduction. This chapter was written by Chikelu Mba and revised by Stefano Diulgheroff and Bonnie Furman, with contributions from Khaled Abulaila, Mariem Bouhadida, Rachel Davis, Ariana Digilio, Elizabeth Fernández and Tiny Motlhaodi.

Chapter 2 – The state of in situ *conservation and on-farm management.* An initial draft was prepared by Prishnee Bissessur, Ehsan Dulloo, Paola De Santis, Nigel Maxted, Stef De Haan, Diana Lope-Alzina, Devendra Gauchan. The final version of the chapter was prepared by the core team, with contributions from Khaled Abulaila, Shakeel Ahmad, Sylvain Aubry, Alvina Avagyan, Martin Brink, Raquel Defacio, Ariana Digilio, Elizabeth Fernández, Mariana Ferreyra, Euriel Godebert, Aluana Gonçalves de Abreu, Susanne Gura, Tiny Motlhaodi, Abdus Salam, Sarah Sensen, Imke Thormann and Isabelle Winkler.

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Abbreviations

ABS	access and benefit sharing
AfricaRice	Africa Rice Center
APSA	Asia and Pacific Seed Association
BGCI	Botanic Gardens Conservation International
CAPGERNET	Caribbean Plant Genetic Resources Network
CATIE	Center for Tropical Agricultural Research and Higher Education
CBD	Convention on Biological Diversity
CePaCT	Centre for Pacific Crops and Trees
CGN	Centre for Genetic Resources (Kingdom of the Netherlands)
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
Commission	Commission on Genetic Resources for Food and Agriculture
Crop Trust	Global Crop Diversity Trust
CSB	community seed bank
CWR	crop wild relatives
DNA	deoxyribonucleic acid
DOI	digital object identifiers
DSI	digital sequence information
DUS	distinctiveness, uniqueness and stability
EAPGREN	East Africa Plant Genetic Resource Network
ECPGR	European Cooperative Programme for Plant Genetic Resources
Embrapa	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
EM-DAT	International Disaster Database
EURISCO	European Search Catalogue for Plant Genetic Resources
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FIGS	focused identification of germplasm strategy
FV/LR	farmers' varieties/landraces
GBIF	Global Biodiversity Information Facility
GBIS	German Genebank Information System
GEF	Global Environment Facility
GeNBIS	Nordic Baltic Genebanks Information System
GFAR	Global Forum on Agricultural Research and Innovation
GG-CE	GRIN-Global Community Edition
GHU	Germplasm Health Unit
GIAHS	Globally Important Agricultural Heritage Systems

GLIS	Global Information System on PGRFA under the International Treaty on Plant Genetic Resources for Food and Agriculture
Global System	Global System on Plant Genetic Resources for Food and Agriculture
GPA	Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture
GPA2	Second Global Plan of Action for Plant Genetic Resources for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture
GRIN	Germplasm Resources Information Network
GRIN-Global	Genetic Resource Information Network
IBP	International Biological Programme
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
ICRAF	World Agroforestry Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
International Treaty	International Treaty on Plant Genetic Resources for Food and Agriculture
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IRRI	International Rice Research Institute
ITC	Bioversity International Musa Germplasm Transit Centre, Belgium
IUCN	International Union for Conservation of Nature
MCPD	multicrop passport descriptors
MLS	Multilateral System under the International Treaty on Plant Genetic Resources for Food and Agriculture
MSB	Millennium Seed Bank
NARS	national agricultural research systems
NBPGR	National Bureau of Plant Genetic Resources (India)
NBSAP	National Biodiversity Strategies and Action Plans
NFP	National Focal Point
NGO	non-governmental organization
NISM	national information sharing mechanisms
NordGen	Nordic Genetic Resource Center
NPAES	National Protected Areas Expansion Strategies
OECD	Organisation for Economic Co-operation and Development
OECM	other effective area-based conservation measures
PGRFA	plant genetic resources for food and agriculture
PPB	participatory plant breeding
PROCITROPICOS	Cooperative Program on Research and Technology Transfer for the South American Tropics
PVS	participatory varietal selection

QTL	quantitative trait locus
RAD	restriction-site associated DNA
REDBIO	Technical Cooperation Network on Plant Biotechnology in Latin America and the Caribbean
REMERFI	Mesoamerican Network of Plant Genetic Resources
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SDIS	SADC Plant Genetic Resources Documentation System
SEARICE	Southeast Asia Regional Initiatives for Community Empowerment
SGSV	Svalbard Global Seed Vault
SMTA	Standard Material Transfer Agreement
SoW	State of the World
SoW1	*The State of the World's Plant Genetic Resources for Food and Agriculture*
SoW2	*The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*
SoW3	*The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture*
SPGRC	Southern African Development Community Plant Genetic Resources Centre
UN	United Nations
UNDP	United Nations Development Programme
UPOV	International Union for the Protection of New Varieties of Plants
WFP	wild food plants
WIEWS	World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture
WorldVeg	World Vegetable Center

Executive summary

This report on the status of the conservation, management and sustainable use of plant genetic resources for food and agriculture (PGRFA) is based primarily on information provided by 128 countries and four regional and 13 international research centres. It covers two reporting cycles over the period from 2012 to 2022. Key sources of information for the report include the data, reports and so-called summative narratives provided by countries through their National Focal Points, as well as thematic background studies and other relevant information. It serves as a follow up to *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoW2), published in 2010.

The state of *in situ* conservation and management

In situ conservation and on-farm management of PGRFA are essential for supporting adaptation processes in their natural or usual habitats. As land use, climate and other factors increasingly threaten PGRFA diversity, the need for their preservation in the wild and in agricultural land has gained recognition. The second chapter of this report addresses the current state of conservation and management of PGRFA *in situ* and on-farm based on reports from 97 countries. The chapter also discusses assistance provided to farmers in disaster situations and the impact of emergency assistance on PGRFA diversity. Additionally, it summarizes threats, challenges, gaps and needs related to the subject.

Over the reporting period, important progress has been made in the number of surveys and inventories of PGRFA undertaken *in situ* and on-farm. A total of 80 countries reported more than 6 200 taxa surveyed, of which approximately 43 percent were food plants from nine use groups: fruit plants, vegetables, roots and tubers, herbs and spices, pulses, cereals, oil plants, pseudo cereals and nuts. Approximately 42 percent of surveyed taxa were reported to be threatened at either the species or varietal levels in at least one survey, including approximately 35 percent of 1 050 taxa of crop wild relatives (CWR) and 38 percent of 405 taxa of wild food plants (WFP) surveyed. Surveys of farmers' varieties/landraces (FV/LR) found that an average of 6 percent of their diversity was threatened globally, although results from nine of 18 subregions were more alarming with 18 percent or more of FV/LR diversity reported as threatened.

During the reporting period, the area of protected *in situ* conservation sites increased by 16 percent to almost 13 million km^2 in 59 reporting countries, compared to the area increasing by 11 percent to 22.4 million km^2 globally. CWR and WFP were mainly conserved passively, as only 6 percent of *in situ* conservation sites in the reporting countries had management plans specifically addressing the conservation of these important plant groups. Almost all countries reported that activities relating to the conservation of wild PGRFA were primarily supported by national institutions either as the sole source of support (51 percent) or in collaboration with others (30 percent).

In situ conservation involved a variety of activities, including the implementation of management practices to maintain high levels of genetic diversity, involvement of local communities, arrangements for *ex situ* conservation of threatened and endangered populations, and/or plans for encouraging public participation.

During the reporting period, farmers continued to maintain and improve significant genetic diversity of locally adapted traditional varieties and landraces on-farm. Approximately 35 million hectares in 51 countries – equivalent to 44 percent of the total crop area of reported sites within areas of high diversity – were cultivated with FV/LR. This includes more than 160 crops and 60 mixed crop groups in over 400 localities globally.

During the reporting period, the number of programmes, projects and activities for on-farm conservation and management of FV/LR increased, totalling more than 1 100 initiatives in 81 countries. These initiatives included efforts to characterize FV/LR, assess the utilization and management of local varieties and traditional knowledge for on-farm PGRFA management, and implement participatory plant breeding. In addition, many countries adopted community-based approaches for managing local crop diversity, such as community seed banks. The country reports indicate that Indigenous Peoples, farmers and local communities are increasingly involved, at least in some countries, in research and training activities. Complementing these efforts, capacity development and marketing initiatives that target farmers and other stakeholders and aim to strengthen on-farm management of PGRFA appear to be on the rise in an increasing number of countries.

The frequency and severity of erratic extreme weather events, as well as the increasing incidence of pests and diseases and the effects of civil unrest and war, appear to have driven a considerable rise in the demand for seed aid to restart crop production after crises. During the reporting period, almost 400 interventions in 48 countries distributed quality seeds and planting materials to farmers and communities as part of emergency aid. Most countries that reported such interventions following disasters are in Africa, while the highest number of interventions was reported by countries in Asia. A major difficulty in such situations is securing quality seeds and planting materials of adapted varieties from local or nearby sources. Climatic events were the cause for about two-thirds of all interventions, with drought as the main cause, followed by floods.

In some countries, a lack of coordination among ministries of agriculture, forestry and environment is a major constraint hindering effective conservation activities. Strengthening linkages with genebanks is essential for enhancing complementarity among *in situ* conservation, on-farm management and *ex situ* conservation approaches. To enhance the adoption of well-adapted quality seeds and planting materials, participatory variety selection and plant breeding with farmers should be strengthened through close cooperation among breeders, genebanks, farmers and community seed banks. Human capacity is also a limiting factor that needs to be urgently addressed to ensure an adequate availability of specialized staff, including taxonomists.

While impacts on the agricultural sector after emergencies are often estimated in terms of monetary and nutrition costs, many countries reported a gap in assessing the impacts of disasters on crop diversity. Additional challenges are the identification of reliable sources of materials and the fact that the germplasm distributed to farmers after disaster situations may not always be fully adapted to the local conditions or the cultural environment.

The state of *ex situ* conservations

Ex situ conservation safeguards PGRFA in a controlled environment and facilitates access by stakeholders. *Ex situ* conservation also provides a complementary backup for material conserved and managed *in situ* and on-farm. The third chapter of this third report addresses *ex situ* conservation efforts worldwide and focuses predominantly on materials maintained in genebanks.

Germplasm collections totalling over 5.9 million accessions are conserved under medium- and long-term storage conditions in over 850 national genebanks in 116 countries, as well as four regional and 13 international genebanks. This represents a 8 percent increase compared to collections reported in 2009. The biological status of the conserved germplasm is documented for 72 percent of the accessions reported. These include approximately 1 532 000 accessions of FV/LR and 727 000 accessions of wild materials, of which approximately 548 000 are CWR and 47 000 are WFP. The remaining accessions are breeding materials and improved varieties. The country of origin is known for approximately 70 percent of the accessions. The crop groups with the largest numbers of accessions conserved are the major food crops, including cereals, pulses, roots and tubers, and vegetables. Most of the accessions (79 percent) are conserved as seed, followed by conservation in field collections and *in vitro*.

At the end of 2022, approximately 41 percent of all *ex situ* holdings were safety duplicated, a significant increase from 15 percent in 2014. Overall, 69 percent of all safety duplicated accessions are conserved as seed at their origin, 2.3 percent in field collections and less than one percent *in vitro*. Over one million accessions (43 percent of the safety duplicated holdings) were deposited at the Svalbard Global Seed Vault (SGSV), demonstrating that countries are taking increasing advantage of the SGSV as a long-term black-box storage facility. However, there is still a need to provide sustainable, long-term cryostorage backup for species that are vegetatively propagated or produce recalcitrant seeds.

The degree of uniqueness is estimated to be approximately 37 percent of total *ex situ* holdings. Regarding unwanted duplications, continued rationalization efforts have resulted in some progress made at both the country level and within international genebanks. However, redundancies within and among collections have remained poorly documented overall and require continued attention. Many species (e.g. *Aframomum corrorima*, *Apium australe, Ensete ventricosum, Manihot peruviana, Oenocarpus mapora, Uapaca kirkiana*, *Vigna minima*) are conserved in only one or very few genebanks, which poses a risk that failure to conserve the material in these genebanks could mean a complete loss of the species from *ex situ* collections.

Between 2012 and 2019, almost 250 000 samples were collected by 366 institutes in 87 reporting countries. Of these, approximately 13 000 samples were CWR and just over 5 000 were WFP. A number of countries report having strategies for targeted collecting, including to address missing genetic diversity, ecogeographic coverage, coverage of targeted taxa (including CWR), and trait-specific gaps (such as resistance to pests and diseases). Although acquisition of germplasm through collecting has improved, many genebanks could still benefit from more targeted collecting based on gap analyses. Despite renewed interest in the acquisition of CWR, collecting wild species often fails due to the unavailability of staff specialized in relevant disciplines, such as taxonomy and phenology.

Germplasm health issues seem to receive increasing attention in the conservation, distribution and use of PGRFA. The increased movement of germplasm within and between countries and continents enhances the potential spread of pests and diseases. Overall, awareness and management of germplasm health issues appear to have improved during the reporting period. However, several national genebanks still lack adequate human and financial resources to effectively monitor germplasm health, which greatly affects germplasm exchange.

Regeneration remains a key challenge for many countries and genebanks. Approximately one-third of the accessions reported by countries were regenerated between 2012 and 2019, while 24 percent need regeneration. In particular, the regeneration of CWR and out-crossing species is problematic for many genebanks. More than 900 000 accessions were regenerated by CGIAR centres and WorldVeg during the reporting period. At the end of 2019, just under 180 000 accessions (20 percent) needed regeneration and the budget to regenerate just over 28 500 accessions was lacking at these centres. Among the regional genebanks, NordGen regenerated 17 percent of its holdings over the reporting period, with 14 percent in need of regeneration.

Documentation has been highlighted as an essential part of genebank management for many years. Despite support provided in this regard, including by the Crop Trust, many countries still lack genebank management information systems and struggle to document passport and other genebank management data. However, the situation shows signs of improvement with the increasing availability of improved open-source software for genebank data management, such as the new GRIN-Global Community Edition. Standardized passport data and data object identifiers (DOIs) are increasingly being applied for germplasm exchange and cross-referencing germplasm in publications. Greater efforts are still needed to train data specialists and genebank managers to adopt and use these improved systems and tools.

Between 2012 and 2019, national genebanks in 87 countries distributed almost 1.3 million accessions, with over 90 percent distributed domestically. The main recipients included national agricultural research centres, farmers, non-governmental organizations (NGOs) and the private sector. Approximately 56 percent of all distributed accessions and 38 percent of distributed samples reported through the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) were of crops listed in Annex 1 of the International Treaty. The remaining 44 percent of distributed accessions were soybean, cotton, tomato, tobacco, *Capsicum, Acacia*, pear, sesame, cocoa, okra, teff, flax, tea, beets, cucumber and melon, each with more than 5 000 accessions distributed.

Notwithstanding the achievements and advances that have been made over the past ten years, many issues that impede the efficient and effective conservation of PGRFA still remain and need to be addressed. *Ex situ* conservation still lacks the necessary political and financial support in many countries, which often results in limited or sporadic funding, lack of sufficiently qualified staff, and insufficient infrastructure and logistics. Key activities, such as viability testing, regeneration and safety duplication, continue to suffer from this lack of support. In addition, several national genebanks lack the human and/or technical capacity necessary to effectively address germplasm health issues.

Existing regional genebanks provide a model for collaboration that could support national programmes by coordinating and pooling resources for training, backup storage and collaboration on essential activities, such as viability and germplasm health testing, regeneration and characterization, including molecular characterization. While this approach could result in cost efficiencies, it would still require political commitment and coordination. Collaboration with universities, other research institutes and the private sector could further enhance the conservation and sustainable use of PGRFA.

The state of sustainable use

During the reporting period, progress was made in the sustainable use of PGRFA, in particular through germplasm characterization, plant breeding, broadening the genetic base of crops through pre-breeding, the utilization of locally adapted varieties and underutilized species, the release of crop varieties and seed delivery systems, and the promotion of diverse farming systems.

Country data indicate a significant increase in the number of accessions characterized, as well as progress in the development of thematic collections for traits of interest between 2012 and 2019. This has facilitated a better understanding and improved exploitation of germplasm collections. By the end of 2019, almost 800 000 germplasm accessions – held by 289 genebanks in 70 countries, and representing 30 percent of the total genebank holdings in these countries – were characterized, on average for 24 traits. Recent advances in biotechnologies, especially next-generation sequencing and high-throughput phenotyping, are increasingly utilized to enhance efficiencies in germplasm characterization and evaluation. An overall increase in the adoption of deoxyribonucleic acid (DNA) marker technologies for the assessment of genetic variation was reported by 53 countries from five regions. However, not all countries have access to these technologies and many lack the capacity to utilize them. Collaboration, capacity building and technology transfer are essential to ensure that all countries can fully benefit from the diversity of PGRFA.

Most existing characterization and evaluation data are not publicly available due to suboptimal information and data management systems. Additionally, the ongoing lack of sufficient characterization and evaluation data often hinders the targeted selection of accessions possessing specific traits and, in this regard, there is a substantial need for improvement.

More than 350 national research organizations from 76 countries reported the use of pre-breeding (the introgression of novel traits from non-adapted materials into breeding populations) for 322 crop species. While pre-breeding activities took place in all regions during the reporting period, they do not appear to have yet become a routine crop improvement strategy. This suggests a largely unused opportunity for strategic collaboration between genebank managers and breeders.

Breeding activities were reported by 87 countries, targeting almost 500 crop species across all major crop groups. While yield continues to be the prioritized trait in crop breeding programmes, resistance to biotic and abiotic stresses – especially as a climate change adaptation strategy – and quality traits for enhanced nutrition are also frequently cited as breeding objectives. The number of countries that report farmer participatory plant breeding more than doubled since SoW2.

Alongside important advances in high-throughput and low-cost genotyping, in particular genome sequencing, significant advances in morphological and biochemical characterization of plants provide new opportunities. Country data indicates an upsurge in the application of modern plant breeding techniques, in particular genomic selection and the more recent genome-editing technologies, including CRISPR/Cas9, during the reporting period.

Activities aimed at increasing intraspecific and/or interspecific diversity in crop production systems were reported by 73 countries. In addition to focusing attention on mixed cropping and crop rotation, diversification initiatives increasingly focus on the introduction of new crops, the re-introduction of crops and the domestication of wild species.

Countries report various measures aimed at enhancing the cultivation of FV/LR and promoting their development and commercialization. More than 500 FV/LR were registered in 29 countries across all regions during the reporting period. Most registrations occurred during the last two years of the reporting period (2018 and 2019), reflecting the resurgent interest in FV/LR and their growing market opportunities. This development is contrasted with the progressive discontinuation in the cultivation of many FV/LR, perhaps reflecting the declining number of farmers – and with them, knowledge associated with FV/LR – as well as the abandonment of marginal cropping areas.

Nearly 1 400 programmes on research, crop improvement, improving processing, public awareness, seed distribution, market development and policy changes for FV/LR and underutilized crops or species, were reported by 75 countries. Of these programmes, 412 are considered specific to FV/LR, whereas 159 specifically target underutilized crops or species.

Informal and formal seed systems co-exist in all countries. Forty countries, more than two-thirds of them developing countries, reported improvements in their seed systems between 2012 and 2019, facilitating farmers' adoption of the most suitable crop varieties. Globally, the global seed market increased in value from USD 36 billion in 2007 to more than USD 50 billion in 2020.

Despite progress in characterization, the limited availability of trait-specific subsets continues to constrain the use of PGRFA in research and plant breeding. Modern biotechnologies and molecular genetic tools remain too costly for regular use in crop breeding in many national programmes, which are often insufficiently funded to even support capacities for traditional breeding.

The cost of quality seeds of suitable crop varieties remains an important constraint to their wider application in many developing countries. This could be mitigated through targeted policies and incentives that address components of the seed value chain.

Despite advances in promoting the development and commercialization of FV/LR and underutilized species, many countries still lack national policies and legal frameworks to support these initiatives. Efforts to increase research and the utilization of PGRFA should be enhanced.

The state of human and institutional capacities

Globally, human and institutional capacities to use and conserve PGRFA have increased since the publication of SoW2, although progress has been uneven across key areas of PGRFA conservation and sustainable use, and across regions and countries. In general, these advances appear inadequate to fully implement GPA2. Strengthening human and institutional capacities remains essential for the implementation of GPA2 and for meeting other related commitments, such as the Sustainable Development Goals and relevant targets of the Kunming-Montreal Global Biodiversity Framework.

During the reporting period, incremental progress has been made in establishing and strengthening national programmes, as well as in developing strategies to guide their operations. The development of National Biodiversity Strategies and Action Plans has been identified as a catalysing factor in this regard. However, less than half the countries (37 countries) reported progress in the development of PGRFA-specific strategies or relevant legislation.

During the reporting period, education and training opportunities, particularly at the secondary school level, increased slightly. However, although approximately 80 percent of reporting countries had postgraduate level educational programmes, 27 percent (6 countries) in sub-Saharan Africa did not. Additionally, the only reporting country from Melanesia, despite being very rich in plant diversity, reported neither undergraduate nor postgraduate education programmes on PGRFA. On the other hand, a significant increase was observed in the number of personnel working in key institutions with higher levels of educational qualifications, typically at the master's and doctoral levels.

In addition to educational institutions, other stakeholders, such as botanical gardens, genebanks, seed networks, research institutes, regional and international organizations, NGOs, foundations, associations and museums, contributed to training and capacity development. Cooperation among universities, networks, research institutes, and regional and international genebanks also improved, leading to joint educational and research activities in 43 percent of reporting countries. The increased use of online tools and platforms, coupled with the development of several innovative teaching materials – including videos and e-learning resources – enhanced participation in training programmes from remote locations.

More than 90 percent of reporting countries are members of networks for the management of PGRFA. These networks remain important hubs of activity for promoting the conservation and sustainable use of PGRFA, and the important benefits of international collaboration are widely recognized among stakeholders. For example, many publications have been produced through participation in these networks.

While some new networks have been initiated and others have renewed their efforts, other important regional networks, such as the Caribbean Plant Genetic Resources Network (CAPGERNET), the Cooperative Program on Research and Technology Transfer for the South American Tropics (PROCITROPICOS) and the Mesoamerican Network of Plant Genetic Resources (REMERFI) in Latin America and the Caribbean have had to pause or cease their activities. Many networks are managed by volunteers and depend on short-term project funds, leading to fragility. In addition, coordination and collaboration among different stakeholders within and among networks at regional and international levels is often suboptimal.

International information systems have expanded and proliferated. Cross-platform interoperability and data-sharing initiatives have been further advanced with the development of the International Treaty's Global Information System (GLIS), including Genesys and WIEWS. The application of DOIs under GLIS has continued to provide opportunities to improve efficiencies in tracing germplasm through research publications. The United Nations General Assembly's adoption in 2017 of SDG Indicator 2.5.1.a on *ex situ* conservation stressed the key role of genebanks in preserving PGRFA and fostered country reporting and dissemination of standardized information through WIEWS.

As of 2019, almost 56 percent of 59 countries reporting on this topic had an operational genebank management information system for PGRFA in place. The recent development of GRIN-Global Community Edition has expanded the opportunities for genebanks to adopt an open-access and user-friendly genebank information management system; 12 countries reported that they are considering its adoption.

Despite the numerous advances, a significant amount of data, particularly from characterization and evaluation trials, are not readily available or publicly accessible. Data standardization remains a major challenge, although the progressive adoption of DOIs and advancements in Artificial Intelligence promise improvements in this area. This situation is even more challenging with regard to data on the geographic distribution of CWR and FV/LR, for which systematic monitoring and inventory remains an unattained objective in all countries. Additionally, traditional knowledge on PGRFA appears to be rarely documented, nor included in information systems where documentation exists.

During the reporting period, only a few countries had a national system for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Many countries reported continued concern over the extent of genetic vulnerability and the need for a greater deployment of diversity in cropping systems. Awareness increased on the importance of establishing mechanisms for monitoring genetic erosion, especially as part of *in situ* conservation approaches.

The number of accessions included under the International Treaty's Multilateral System (MLS) increased from approximately 600 000 in 2014 to more than 2.3 million in 2022, indicating the progress made in making PGRFA available for research, breeding and training activities under the MLS using the Standard Material Transfer Agreement (SMTA) of the International Treaty. Notably, some national and regional genebanks also use the SMTA for the distribution of non-Annex 1 materials.

Farmers' Rights, as provided for in Article 9 of the International Treaty, remained topical during the reporting period, as indicated by the development of an inventory of national measures, best practices and lessons learned from the realization of Farmers' Rights.

There was an increase in the routine participation of farmers, Indigenous Peoples, local communities, and the wider public in decision making and the co-development of solutions related to PGRFA. International institutions, countries and national stakeholders increasingly instituted mechanisms to foster this pluralism. However, there remains significant scope for increasing the participation of these groups in decision making related to the management of PGRFA, especially by strengthening capacities for facilitating participatory processes.

Almost 80 percent of 89 countries reporting on this topic had a public awareness programme in place. While no formal programme exists in Northern America, in the other regions the percentage of countries with a programme varied between 63 percent in Latin America and the Caribbean to 90 percent in sub-Saharan Africa. The increasing number of awareness-raising activities corresponds with an increase in public understanding of the complexities of the management of PGRFA. It appears that decision makers, civil society and farming communities have become more aware of the importance of PGRFA and its associated challenges. Greater attention is given to the importance of conserving local crop diversity by promoting the diversity of native varieties, as well as local seeds and traditional food products and their nutritional value. New actors with strong linkages to farmers, Indigenous Peoples and rural communities – such as civil society organizations, social movements and seed networks – increasingly participate in the dissemination of information. Additionally, the increased use of digital and social media platforms has expanded the reach of information dissemination on PGRFA to a much broader audience, including young people.

Collaboration among national stakeholders and institutions remains weak, while initiatives that are driven by civil society organizations are usually insufficiently supported and not well integrated into national programmes. Despite significant progress made during the reporting period, there is a need to strengthen academic institutions and develop educational programmes on plant breeding, genetic improvement and biotechnology in all regions. Similarly, there is a need for more targeted training courses, in all technical and legal aspects of PGRFA, aimed at a greater number of professionals, farmers, Indigenous Peoples and civil society.

A younger generation of professionals is needed to replace retiring experts in many countries, with efforts to build sufficient capacity and transfer knowledge. The chronic lack of research funding, including for scholarships, post-doctoral fellowships and long-term breeding programmes, remains a major bottleneck to strengthening capacities in the management of PGRFA. Weaknesses in collaboration and partnerships within and between national higher education institutions, research centres, networks and international institutions also remain unaddressed in many countries.

Although it is increasingly addressed, there remains scope to improve the interoperability of existing information systems through the adoption of shared and open standards. Data on CWR and FV/LR are insufficiently covered by existing information systems. There is also often a lack of technological capacity to both manage and access information on PGRFA. Overall, key constraints to strengthening information systems are weaknesses in expertise on plant taxonomy, information management and bioinformatics, a lack of necessary digital infrastructure, and suboptimal funding and financial support.

There remains a critical need to develop mechanisms for monitoring genetic erosion, especially for PGRFA conserved *in situ*, in most national and regional contexts. Surveys and baseline studies are needed, as well as indicators to assess genetic vulnerability and erosion. The lack of dedicated budgetary resources or long-term funding, as well as weak coordination among stakeholders, remain significant hurdles to assess and effectively address genetic erosion.

National communication strategies and targeted public awareness programmes on the value of PGRFA require continued renewal and dedicated resources. Although a number of countries have an overall public awareness programme, interinstitutional coordination, collaboration and partnerships on communication activities – including engagements with media organizations – remain weak across all regions, resulting in shortcomings in information dissemination. Gaps also remain in tailoring effective communication messages to a diversity of audiences and delivering these in local languages. The lack of funding and dedicated budgets for communication constituted a key constraint for public awareness raising.

Chapter 1

INTRODUCTION

Chapter 1

Introduction

1.1 Plant genetic resources for food and agriculture

The term "plant genetic resources for food and agriculture" (PGRFA) refers to any genetic material of plant origin, including reproductive and vegetative propagating material containing functional units of heredity, of actual or potential value for food and agriculture (FAO, 2009). PGRFA therefore encompass: (i) cultivated crop varieties (cultivars) that are newly developed; (ii) obsolete cultivars; (iii) primitive cultivars (landraces) and farmers' varieties; (iv) crop wild relatives (CWR), i.e. wild populations related to cultivated species; (v) wild food plants (WFP); and (vi) breeding and research materials or special genetic stocks (including elite and current breeders' lines and mutants). While the deoxyribonucleic acid (DNA) and other hereditary materials of these plants are also considered PGRFA, the term is commonly used in reference to whole plants and their propagules. PGRFA are typically found in the wild, in farmers' fields and in experimental fields. They can be safeguarded *ex situ* in genebanks as germplasm accessions and *in situ* in their natural habitats.

With a continually increasing global population, the devastating impacts of climate change, dwindling agricultural water resources and arable land, strife, pandemics and many adverse socioeconomic drivers, food insecurity and malnutrition have been worsening over the past several years (FAO *et al*., 2018, 2019, 2020, 2021, 2022). Healthy, nutritional diets are increasingly unaffordable and growing numbers of people do not have access to enough food. The COVID-19 pandemic, international armed conflicts and civil wars have exacerbated food insecurity and malnutrition globally in recent years, especially in the Global South. Indeed, with food production lagging behind the levels projected to be needed to meet an increasing demand for food, it is probable that efforts to eradicate hunger and malnutrition by 2030 in line with the United Nations Sustainable Development Goals (SDGs) (UN General Assembly, 2015) are not on track to succeed. Given that 80 percent of food is plant-based, PGRFA are critically important to efforts to attain food security and good nutrition.

1.2 Multilateralism in the conservation and use of plant genetic resources for food and agriculture

Over the past five decades, the international community has consistently called attention to the importance of PGRFA to food security and nutrition, and to the interdependence of countries regarding the conservation and sustainable use of these resources, access to them and the equitable sharing of benefits arising from their use (Sonnino, 2017). For these reasons, significant effort and resources have been invested in making PGRFA freely available, especially for research and development, through various normative processes and instruments.

For example, in 1957, soon after it was established as a specialized agency of the United Nations (UN) mandated with addressing global food security and nutrition, the Food and Agriculture Organization of the United Nations (FAO) started publishing a newsletter on PGRFA. In 1959, the Tenth Session of the Organization's Conference called for immediate action on the collection and conservation of landraces and CWR (FAO, 1997). This was followed by major technical meetings on PGRFA. A technical meeting on plant exploration and introduction took place in 1961, and this was a prelude to the establishment of the FAO Panel of Experts on Plant Exploration in 1963. The Panel of Experts was tasked with advising the Organization on the collecting, conservation and exchange of germplasm and with setting international guidelines for these activities. In 1967, a landmark event, the Technical Conference on Exploration, Utilization, and Conservation of Plant Genetic Resources, was organized jointly by FAO and the International Biological Programme (IBP).

The results of these initiatives included streamlined germplasm conservation and distribution, and the establishment of international agricultural research centres in the regions with the greatest diversity. Progress was facilitated by the development of guidelines, by the Panel of Experts, on the establishment of a global network for *ex situ* conservation and an associated plan of action (Frankel and Hawkes, eds, 1975; Scarascia-Mugnozza and Perrino, 2002). A proposal put forward by the Panel of Experts and considered by a further FAO/IBP technical conference, held in 1973, and subsequently by the Technical Advisory Council of the Consultative Group on International Agricultural Research (CGIAR), formed the basis for the creation of a coordinating centre, the International Board on Plant Genetic Resources within FAO. This body would evolve into the International Plant Genetic Resources Institute, a CGIAR centre later renamed Bioversity International, which is now a constituent part of the Alliance of Bioversity International and CIAT (International Center for Tropical Agriculture).

Over the subsequent decades, the international community, mostly under the auspices of the mechanisms of FAO, has collaborated on the conservation and use of PGRFA, including by devising means for accessing these resources and for the equitable sharing of the benefits arising from their use. FAO's programme of normative work in this field has been implemented through its Commission on Genetic Resources for Food and Agriculture (Commission), which was established in 1983 as the Commission on Plant Genetic Resources. In 1995, the Commission's remit was expanded to cover all components of biodiversity of relevance to food and agriculture.

1.3 The Global System on Plant Genetic Resources for Food and Agriculture

Through the Commission, FAO provides its members and myriad partners with a forum for the discussion and negotiation of matters relevant to genetic resources for food and agriculture. It was in this context that the Global System on Plant Genetic Resources for Food and Agriculture (Global System) was created under the Commission's auspices. The Global System is a set of policy instruments and mechanisms intended to promote the safeguarding of PGRFA, their availability and their sustainable use (FAO, 2010; Frison, Lopez, and Esquinas-Alcazar, eds, 2011).

The principal agreements included under the Global System are the following:

- *The International Undertaking on Plant Genetic Resources for Food and Agriculture*, which was adopted by the FAO Conference in 1983 with the objective of ensuring "that plant genetic resources of economic and/or social interest, particularly for agriculture, will be explored, preserved, evaluated and made available for plant breeding and scientific purposes. 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" (FAO, 1983).
- *The Convention on Biological Diversity* (CBD), which is the international agreement for "the conservation of biological diversity, the sustainable use of its components and the fair

and equitable sharing of the benefits arising out of the utilization of genetic resources" (United Nations, 1992). PGRFA constitute an integral part of biodiversity and, as such, are covered by the CBD and its recently adopted Kunming-Montreal Global Biodiversity Framework.

- *The International Treaty on Plant Genetic Resources for Food and Agriculture* (International Treaty), which is a revision to the International Undertaking and is in line with the CBD. The International Treaty, in harmony with the CBD, caters specifically to PGRFA, for which it is the internationally agreed governance mechanism. It recognizes plant genetic diversity as a global public good that needs to be preserved for humankind in a joint international effort for many generations to come in view of the fact that all countries in the world are interdependent when it comes to crop diversity. It was adopted by the Thirty-first Session of the FAO Conference on 3 November 2001 and entered into force on 29 June 2004.

The actions proposed by the United Nations Conference on Environment and Development (UNCED) in June 1992 to strengthen the FAO Global System included the preparation of periodic reports on the state of the world's PGRFA and a rolling global cooperative plan of action on PGRFA (FAO, 1997). The ensuing periodic reports and rolling global plans have been the following:

- ***The State of the World's Plant Genetic Resources for Food and Agriculture* (SoW1)** was developed pursuant to a decision taken in 1991 by the Twenty-sixth Session of the FAO Conference (FAO, 1997). Information for compiling the SoW1 was obtained primarily from 154 country reports, which had been prepared based on guidelines developed by FAO. Through these reports, countries provided status updates on indigenous and native 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. Additional information was obtained from the FAO-managed database the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS), which contained countries' responses to two FAO questionnaires, one on PGRFA and one on forest genetic resources. Information provided by CGIAR centres, obtained from the then recently conducted external review of the CGIAR genebanks, was also incorporated into the SoW1, as were outputs from FAO's electronic conferences on plant breeding and genetic diversity, in which about 200 individual scientists participated. The publication thus provided the first comprehensive overview of the state of diversity, genetic vulnerability and genetic erosion in crops and other plants relevant to food security and nutrition, and of capacities for the conservation and use of these resources. The draft of the SoW1 was welcomed as the first comprehensive worldwide assessment of the state of plant genetic resource conservation and use at the Fourth International Technical Conference on Plant Genetic Resources, which was convened by FAO and held in Leipzig, Germany, in June 1996, and attended by representatives of 150 countries.
- **The *Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture* (GPA)** was adopted, along with the "Leipzig Declaration", at the 1996 International Technical Conference (FAO, 1996). The GPA was conceived as a costed plan to make the Global System fully operational. It drew on the above-mentioned country reports and the outcomes of visits by FAO staff and consultants to more than 100 countries. These visits provided the basis for the preparation of 15 subregional synthesis reports, which were used for discussions at most of a series of 12 regional and subregional meetings held in 1995 and 1996, in which a total of 143 countries and several international and non-governmental organizations (NGOs)

participated. Recommendations for the GPA were formulated and adopted at each of the regional and subregional meetings. On its adoption, the GPA became the internationally agreed framework for the conservation, exploration, collecting, characterization, evaluation and documentation of crop genetic resources. The GPA – envisaged as a rolling plan to be reviewed periodically – consisted of 20 priority activity areas, presented under four main themes: *In Situ* Conservation and Development; *Ex Situ* Conservation; Utilization of Plant Genetic Resources; and Institutions and Capacity Building.

- ***The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoW2)**. The Commission, at its Eighth Regular Session in 1999, agreed that preparation of a second report on the state of the world's PGRFA and an amendment to the GPA should be considered. At its Ninth Regular Session, in 2002, the Commission agreed that work should progress on the development of the SoW2 and that the country-driven preparatory process for the SoW2 should be fully integrated with the process of monitoring the implementation of the GPA on the basis of a set of indicators that was under development. At its Tenth Regular Session in 2004, the Commission, envisaging that the SoW2 would be completed in 2008, reiterated that it should provide objective information and analysis and identify priorities – and thus provide a basis for updating the GPA. The Commission confirmed that the SoW2 should, as far as possible, focus on changes that had occurred since the publication of the SoW1. It also approved the list of thematic background studies and took note of the draft guidelines for the preparation of country reports, which it observed should be further considered and refined at regional meetings.

  At its Eleventh Regular Session, in 2007, the Commission requested that the Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture, at its Fourth Session in 2009, review and guide the finalization of the draft of the SoW2 for the consideration of the Commission at its next regular session. It also requested FAO to submit to the same session a proposed plan for the process of updating the GPA. At its Twelfth Regular Session, in 2009, the Commission endorsed the SoW2 as the authoritative assessment of the PGRFA sector (FAO, 2010). The SoW2 provided a snapshot of the status of the conservation and sustainable use of PGRFA and the institutional and human capacities that underpin these activities. Importantly, in addition to describing the changes that had occurred in the various domains of PGRFA management, it also identified gaps and needs related to these domains.

  The SoW2 was prepared based mostly on information provided by countries through 113 country reports, following *the Guidelines for the Preparation of the Country Reports*, which were made available in 2005. The preparation of many of the country reports benefited from information that had been lodged on national information sharing mechanisms (NISMs) (see Section 5.2.1). The information provided by countries was augmented by information from the scientific literature, thematic background studies and other technical publications. Additionally, specific information from the CGIAR and other regional and international genebanks was gathered in 2008 under the coordination of the System-wide Genetic Resources Programme (SGRP).
- **The *Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture* (GPA2)**. For 15 years, from 1996 to 2011, the GPA was the internationally agreed framework for national, regional and global efforts to conserve and sustainably use PGRFA and to share equitably and fairly the benefits that derive from their use. In endorsing the SoW2 in 2009, the Commission agreed to update the GPA and requested FAO to prepare the update based primarily on the SoW2, taking

into account, in particular, the gaps and needs identified, further contributions envisaged from governments, and inputs from regional meetings and consultations. As the GPA was a supporting component of the International Treaty, it was envisaged that the updated GPA would be important for the identification of future priorities for the International Treaty's funding strategy. The Commission thus requested the involvement of the Secretariat of the International Treaty in the updating process. At its Thirteenth Regular Session, in July 2011, the Commission agreed on the GPA2, welcomed it as a major achievement in global efforts to conserve and sustainably use PGRFA, and emphasized its essential role in the implementation of the International Treaty. The GPA2, which was adopted by the FAO Council in November 2011 on behalf of the FAO Conference (FAO, 2011), contains 18 priority activities, grouped into four main themes: *In Situ* Conservation and Management; *Ex Situ* Conservation; Sustainable Use; and Building Sustainable Institutional and Human Capacities (FAO, 2012).

1.4 Preparation of *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture*

The Commission, at its Fourteenth Regular Session, in 2013, endorsed the proposed timeline for the preparation of *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoW3), with the presentation of the draft report foreseen for its Eighteenth Regular Session in 2021. It stressed that the monitoring of the GPA2 and the preparation of the SoW3 should be fully integrated, and invited FAO to engage with relevant international organizations to ensure their participation in the preparation of the SoW3 from an early stage. In 2017, at its Sixteenth Regular Session, the Commission revised the timeline for the preparation of the SoW3 and postponed its launch to its Nineteenth Session, scheduled for 2023.

Timeline

As with the previous global assessments, it was envisaged that the SoW3 would be based on information provided by countries and international organizations, and in thematic background studies developed to support the preparation process. In a departure from the previous assessments, the preparation of the SoW3 would no longer rely on stand-alone country reports but would instead be based on data gathered during two reporting periods: January 2012 to June 2014, with reports due by 30 November 2015; and July 2014 to December 2019, with reports due by 31 December 2020. Countries reported on the first reporting period between January 2015 and December 2017 and commenced reporting on the second period in January 2020.

Reporting format

The reporting format for the SoW3 consisted of a questionnaire made up of the 63 indicators for monitoring the implementation of the 18 priority activities of the GPA2, and 51 questions intended to clarify the indicators. For the first reporting cycle, the reporting format was accessed through the online WIEWS Reporting Tool. For the second cycle, the Commission agreed on a slightly revised reporting format based on 58 indicators and 48 questions. During the second reporting cycle in 2020, National Focal Points (NFPs) complemented the data provided with a summative narrative, which detailed progress made in the implementation of the GPA2 between January 2012 and December 2019 and described remaining constraints to implementation. FAO published the guidelines *Preparation of Country Reports for The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (FAO, 2019), in all the official languages of the Organization, to facilitate reporting. The use of the WIEWS

Reporting Tool allowed standardized data reporting by NFPs and national stakeholders, and the eventual collation and analyses of the data.

Reporting process

A total of 78 countries reported on the first reporting period (2012–2014), although not every country replied to all the questions. In 2019, FAO invited Member Nations to report on the second reporting period by December 2020. They were also given the opportunity to retrospectively report, revise or complement data related to the first reporting period. More detailed information – the user manual of the online WIEWS Reporting Tool and the guidelines for country reporting – was made available online in all FAO official languages. A glossary and a comprehensive list of frequently asked questions, including detailed explanations for all the questions and indicators, were also made available online. Over 440 participants from more than 75 countries participated in FAO-organized online training sessions in English, French and Spanish. Recordings of the training sessions were made available to participants via the internet. Additional online sessions for individual countries were held if requested by NFPs.

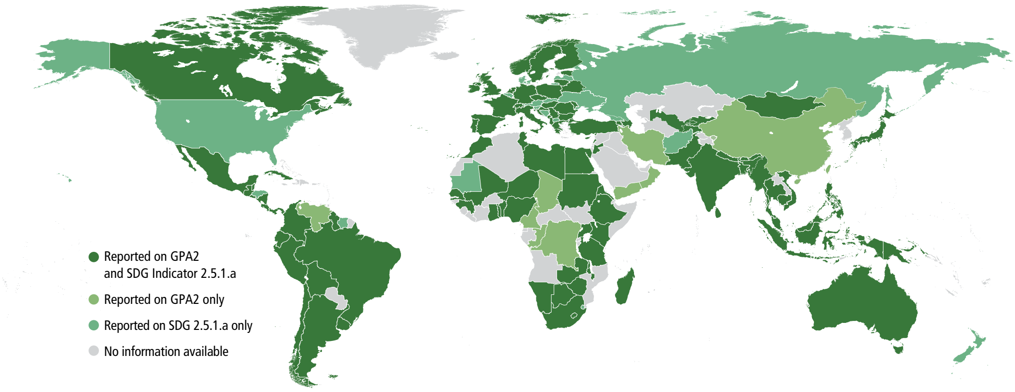
Meanwhile, the United Nations General Assembly had adopted the 2030 Agenda for Sustainable Development, including the 17 SDGs and 169 targets (UN General Assembly, 2015) and, two years later, the indicators for monitoring progress towards the SDGs (UN General Assembly, 2017). The indicator used to oversee progress on the conservation of *ex situ* collections under the GPA2 became SDG Indicator 2.5.1.a, a Tier I indicator[1] of the SDG monitoring framework to be reported on every year from 2017 onwards, with FAO acting as the custodian agency. Because of this development, the number of countries reporting on the indicator grew rapidly, rising from 67 to 116 between 2014 and 2022. Data reported were used to complement those from the two reporting cycles on the implementation of the GPA2.

As of 29 June 2021, a total of 129 countries had nominated a NFP, 55 had completed online reporting for the second reporting cycle, and one had provided a stand-alone report. In addition, 16 countries were at an advanced stage of the reporting process and 18 had just begun. Fifty of these countries also provided information pertinent to the first reporting period. Six of the 50 countries reported for the first time on the first reporting period, bringing the total number of countries that reported on the first period to 84. In all, 12 international organizations reported on both periods. At its Eighteenth Regular Session, in October 2021, the Commission, taking into account the delays to reporting caused by the COVID-19 pandemic, agreed to extend the deadline for country reporting to the end of December 2021. A draft SoW3 was made available to the Commission at its Nineteenth Regular Session in July 2023, and to the Tenth Session of the Governing Body of the International Treaty in November 2023. Based on comments received and taking into consideration data from the latest reporting on SDG Indicator 2.5.1.a, a second draft was produced and made available in August 2024 for further inputs from Members and observers. The comments and inputs received from 23 NFPs and experts were addressed and incorporated into the final version of the report.

As of September 2024, a total of 128 countries and four regional and 13 international research centres had provided information for the SoW3, sourced from over 1 650 stakeholders. Of these, 116 countries and all the regional and international research centres had provided information on their base collections in line with SDG Indicator 2.5.1.a; 106 countries and 12 international organizations had provided data on the implementation of the GPA2 between 2012 and 2019 (Figure 1.1). These data, which emanated from the two reporting cycles, January 2012 to June 2014 and July 2014 to December 2019, respectively, together with the country summative narratives on progress and remaining gaps and constraints, and the latest annual reports on SDG Indicator 2.5.1.a as of the beginning of 2023, constituted the core sources of information for the report.

[1] An indicator with an internationally agreed methodology and a global reporting rate equal to or higher than 50 percent.

FIGURE 1.1
Countries contributing to *The Third Report of the State of the World's Plant Genetic Resources for Food and Agriculture*



Notes: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.

1.5 Structure of the report

The SoW3 consists of five chapters. Chapter 1 – Introduction, reviews multilateral efforts spanning several decades to conserve and use PGRFA. The SoW3 is presented as the most recent addition to the continually growing suite of policy instruments and mechanisms that constitute the Global System for PGRFA. The role of periodic global assessments, such as the SoW3, in setting internationally agreed priorities through a rolling global plan of action is underscored. Snapshots of the global status of institutional and human capacities for the conservation and use of PGRFA are presented in Chapters 2 to 5. Chapter 2 focuses on the conservation of CWR and WFP in their natural habitats and on-farm management of farmers' varieties/landraces (FV/LR) and is based on the contributions from 97 countries. Chapter 3 is devoted to the management of PGRFA *ex situ* in genebanks. Information from 126 countries and 17 regional and international research centres was used to prepare this chapter. Chapter 4, which considers the sustainable use of PGRFA, addresses both the direct use of PGRFA by farmers and other end users, and indirect uses in plant breeding and research. Seed systems, the vehicle for getting the benefits of PGRFA to people, are also discussed in this chapter. Information from 99 countries and about ten international research centres was used in its preparation. Chapter 5 reviews the status of the institutional and human capacities that underpin the functioning of national PGRFA programmes, networks and information systems. Reports from 102 countries were the main source of information for the preparation of this chapter.

Information from five thematic background studies also contributed to the preparation of the report. These five studies respectively address climate change, nutrition, genotyping and phenotyping of PGRFA, novel biotechnologies and germplasm exchange.

The report follows the regional distribution of countries used by the United Nations Statistics Division for reporting on the SDGs (Annex 2). It should be noted that this regional distribution does not necessarily follow the regional distribution of countries as determined for the election of Members of the FAO Council[2] or the Commission.

[2] Further information at https://www.fao.org/governing-bodies/council

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Chapter 2

THE STATE OF *IN SITU* CONSERVATION AND ON-FARM MANAGEMENT

Chapter 2

The state of *in situ* conservation and on-farm management

2.1 Introduction

The conservation of wild and cultivated PGRFA is essential to long-term food security and to efforts to address the many challenges facing agriculture in the context of climate change, habitat loss and the decline of biodiversity. *In situ* conservation plays a critical role in the maintenance of plant diversity within natural habitats and traditional farming systems.

In situ conservation of PGRFA involves the active management and monitoring of target plant populations of species in their natural habitats (FAO, 2017). For wild PGRFA, it entails the conservation of CWR and WFP mainly in protected areas and in areas under other effective area-based conservation measures (OECMs).[1] For cultivated species, it includes the management of genetic resources within the traditional agricultural systems where they developed their distinct characteristics. This approach involves the continued cultivation, selection and use of traditional crop varieties and their wild relatives by farmers in the environments where these plants evolved.

CWR are wild plant species that are genetically related to domesticated crops. They play an essential role in providing beneficial traits for crop improvement (Maxted *et al.*, 2008; FAO, 2017). These traits include resistance to pests and diseases, tolerance to environmental stress and improved nutritional qualities. CWR are found in diverse habitats, including forests and grasslands, areas surrounding farmers' fields and disturbed environments. They serve as a genetic reservoir for breeding new crop varieties that are more resilient to changing climates and other stress factors.

WFP are species that are not necessarily directly related to domesticated crops but are harvested and consumed by local communities for their nutritional and cultural values. These plants provide essential food sources, especially during periods of food scarcity, and contribute to dietary diversity by supplying vitamins, minerals and other nutrients that may be lacking in staple crops (Heywood, 2013). WFP are typically found in natural or semi-natural ecosystems, such as forests, wetlands and savannahs, and are integral to the diets of many Indigenous Peoples, as well as of local communities.

FV/LR are traditional crop varieties that have been developed, maintained and cultivated by farmers over many generations. Unlike modern commercial varieties, these PGRFA are characterized by their genetic heterogeneity and adaptability to local environmental conditions, making them crucial to the maintenance of agricultural biodiversity and resilience (Brush, 2004; FAO 2019a). These varieties are often grown in small-scale, low-input farming systems, where they are selected for traits such as drought tolerance, pest resistance and taste preferences.

In situ conservation involves implementing strategies that protect plant species in their natural habitats while allowing the ecological

[1] An OECM is a geographically defined area other than a protected area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity, with associated ecosystem functions and services and, where applicable, cultural, spiritual, socioeconomic and other locally relevant values are maintained.

and evolutionary processes that shape them to continue. It often encompasses creating protected areas, establishing sustainable land-use practices and working with local communities to maintain traditional agricultural practices that support genetic diversity.

The conservation of CWR *in situ* is particularly important because their genetic diversity can only be fully preserved and utilized if these plants are allowed to continue evolving in their natural habitats (FAO, 2013). This dynamic conservation approach enables CWR populations to adapt to environmental changes, making them a valuable resource for the future of agriculture. A comprehensive *in situ* conservation strategy for CWR should include the identification and management of priority species and habitats, the establishment of genetic reserves, and the development of national and regional conservation plans (FAO, 2010; 2019a).

Similarly, *in situ* conservation of WFP involves protecting the ecosystems in which these plants grow, ensuring that they are harvested sustainably and preserving the traditional knowledge associated with their use and management. The loss of WFP because of habitat destruction, overharvesting and climate change poses a serious threat to food security and biodiversity (FAO, 2017). It is therefore important that strategies for conserving these resources integrate ecological, social and cultural dimensions that allow them to be safeguarded for future generations.

Conservation of FV/LR occurs primarily through on-farm management, whereby farmers continue to grow, select and share these varieties within their communities. This form of conservation allows varieties to adapt dynamically in response to changing environmental and socioeconomic conditions, thereby preserving their genetic diversity and the cultural heritage associated with them (FAO, 2010). This genetic diversity is important to the livelihood strategies of farmers, providing them with opportunities to respond to changes in market demands, labour availability and other socioeconomic and cultural factors.

The conservation of FV/LR is intertwined with the preservation of the traditional knowledge, farming practices and local seed systems that sustain their diversity. Supporting on-farm management of FV/LR requires policies and initiatives that recognize the role of farmers as custodians of biodiversity, promote access to diverse planting materials and protect Farmers' Rights to save, use and exchange seeds (FAO, 2019a).

In situ conservation of wild and cultivated PGRFA is critical for sustaining the genetic diversity of plant species that are not well represented in *ex situ* collections, such as genebanks and botanic gardens (FAO, 2010; see Chapter 3). Together, these approaches provide a comprehensive framework for conserving plant genetic diversity.

Despite its importance, *in situ* conservation faces several challenges, including habitat loss, agricultural expansion, climate change, and the erosion of traditional knowledge and practices. Addressing these challenges requires integrated approaches that combine conservation science, sustainable agricultural practices and community engagement. The development of national and regional strategies that include both *in situ* and *ex situ* conservation measures also strengthen relevant legal frameworks and improve collaboration among stakeholders and are key to combatting these challenges (FAO, 2019a).

In situ conservation of PGRFA is a cornerstone of sustainable agriculture and food security. Preserving the genetic diversity of CWR, WFP and FV/LR in their natural and agricultural environments ensures that these species and varieties continue to evolve and adapt, supporting resilient and diverse food systems. Effective *in situ* conservation strategies must integrate ecological, cultural and socioeconomic considerations, drawing on the knowledge and participation of local communities to sustain these invaluable resources for future generations.

2.2 Overview of *in situ* conservation and on-farm management

In situ conservation and on-farm management of PGRFA allow these resources to adapt continuously to their natural or customary environments. With growing threats to PGRFA diversity from land-use changes, climate change and other factors, the importance of *in situ* and on-farm conservation has become increasingly recognized. This chapter reviews the current state of *in situ* and on-farm conservation, based on data from 97 countries. It highlights the support provided to farmers in crisis situations and the effects that such aid has on PGRFA diversity. It also outlines threats, challenges, gaps and needs related to *in situ* conservation and on-farm management of PGRFA.

Surveying and inventorying of PGRFA *in situ* and on-farm progressed significantly during the reporting period. A total of 80 countries report more than 6 200 surveyed taxa, approximately 43 percent of which were food plants from nine categories: fruits, vegetables, roots and tubers, herbs and spices, pulses, cereals, oil plants, pseudo-cereals and nuts. Approximately 42 percent of surveyed taxa were found to be threatened at the species or variety level in at least one survey, including about 35 percent of 1 050 CWR and 38 percent of 405 WFP taxa. Surveys of FV/LR indicated that, on average, 6 percent of their diversity was threatened globally. However, in nine of 18 subregions, 18 percent or more of FV/LR diversity was reported to be threatened at least once.

As many *in situ* conservation sites fall within the mandate of ministries of forestry or the environment, many countries highlighted the need for increased cooperation among the ministries involved. Countries also report a decrease in capacity in botanical taxonomy, a field in which expertise is needed for the identification and monitoring of PGRFA.

During the reporting period, the area covered by protected *in situ* conservation sites expanded by 16 percent to cover nearly 13 million km² across 59 reporting countries. Globally, the extent of protected areas increased by 11 percent, reaching 22.4 million km². Conservation of CWR and WFP was primarily passive, with only 6 percent of conservation sites having management plans specifically for these important plant groups. National institutions were the main source of support for wild PGRFA conservation, either alone (51 percent) or in partnership with others (30 percent). *In situ* conservation activities included managing genetic diversity, engaging local communities, arranging *ex situ* conservation for at-risk populations and planning for public participation.

Farmers continued to preserve and enhance significant amounts of FV/LR genetic diversity on their farms during the reporting period. Eighty-one countries report a total of more than 1 100 initiatives targeting on-farm conservation and management of FV/LR, with characterization and evaluation activities the most frequently reported. In 51 countries, farmers cultivated a total of approximately 35 million ha of FV/LR, which accounted for 44 percent of the total crop area in regions of high diversity. This included more than 160 crops and 60 mixed crop groups across more than 400 localities worldwide.

Many countries report the adoption of community-based approaches, such as community seed banks (CSBs), and farmers' involvement in research and training activities appears to have grown during the reporting period. Efforts to strengthen on-farm management through capacity building and marketing initiatives for farmers and other stakeholders are increasingly reported.

The growing frequency and severity of extreme weather events and pest and disease outbreaks, as well as the impacts of civil unrest and war, have led to increased demand for seed aid to restore crop production after crises. During the reporting period, nearly 400 interventions in 48 countries resulted in the distribution of quality seeds and planting materials to farmers as emergency aid. Most of these interventions took place in Africa. However, the highest quantities of material were distributed in Asia. Agricultural productivity, as opposed to the restoration of crop diversity, was the primary focus of most of the interventions reported, with only a few crop species and varieties per crop selected for distribution. A significant challenge in such emergencies is sourcing quality seeds and planting materials from locally adapted varieties. Climatic events caused about two-thirds of all interventions, with droughts being the most common type of event, followed by floods. While the impact of emergencies on agriculture is often measured in terms of financial and nutritional costs, many countries lack methods for assessing the effects of disasters on crop diversity.

Countries reported that engaging with diverse stakeholders, including local communities, is necessary for the effective conservation and management of PGRFA *in situ* and on farm. They emphasized the value of participatory crop improvement, notably participatory plant breeding (PPB) and participatory variety selection (PVS), in promoting farmer engagement. The registration of FV/LR emerged as a relatively new development for promoting the conservation and sustainable use of these resources.

FAO's Globally Important Agricultural Heritage System (GIAHS), which creates revenue for local communities through agrotourism and local value chain development, is one initiative that promotes the sustainable use of local crop diversity. The GIAHS programme aims to conserve unique agroecosystems in a cross-sectoral manner, linking agricultural resources, including PGRFA, with cultures of local communities. FAO has supported the designation of 62 systems in 24 countries as agricultural heritage sites between 2005 and 2020.

According to the country reports, the use of CSBs fostered the conservation and distribution of FV/LR. Twenty-one countries from several different regions report the establishment of a total of 600 CSBs during the reporting period. Countries report the use of 550 different plant species in the traditional diets of Indigenous Peoples and local communities, 75 of which were used for food, 52 for beverages and 400 for medicinal purposes.

2.3 *In situ* conservation of crop wild relatives and wild food plants

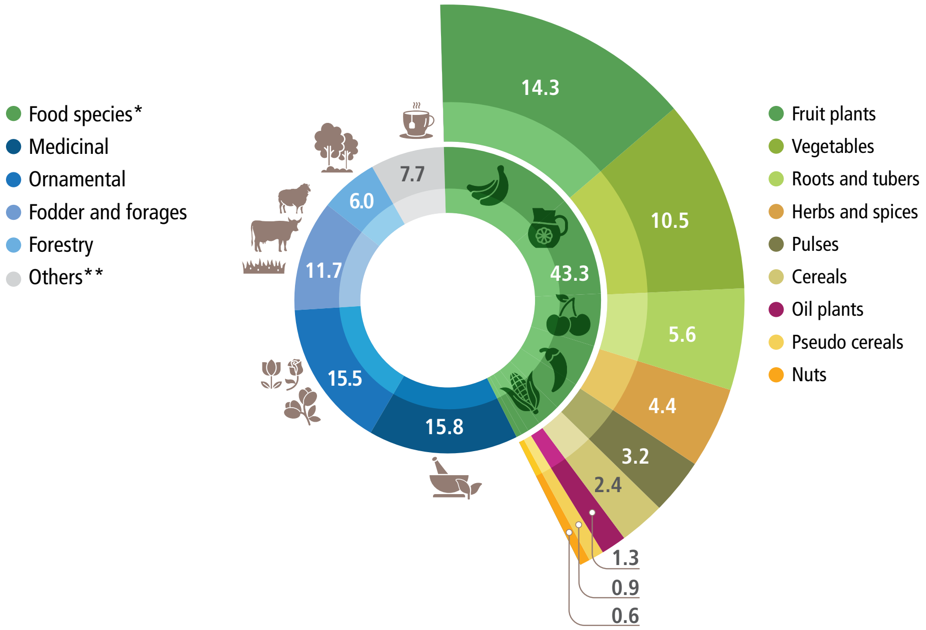
Surveying PGRFA *in situ* and on farm, and developing and updating inventories of these resources, is essential if their availability, distribution and conservation status – as well as the threats they face – are to be understood. Information of this kind allows the development of effective policies and strategies for conservation and sustainable use. CWR and WFP are the two main target groups of surveys and inventories of *in situ* conservation areas, while surveys and inventories on farm mostly target FV/LR. Surveying and inventorying these three groups of PGRFA reduces the risk of losing them in the context of global warming and rapid social, cultural and economic changes.

A total of 80 countries reported on more than 6 200 taxa of CWR, WFP and FV/LR surveyed and inventoried[2] *in situ* and on-farm during 2012–2019. About 43 percent of these taxa were food plants from nine use groups (Figure 2.1).

Among the PGRFA surveyed, countries also identified those that were considered to be "threatened" – defined as "any crops, crop varieties, CWR or WFP that are no longer cultivated or no longer occur *in situ* in most of their previous areas of cultivation or occurrence" (FAO, 2020). About 42 percent of the taxa surveyed were reported to be threatened either at the species or varietal levels in at least one survey.

[2] For the purposes of this report, the terms survey and inventory are used interchangeably as synonyms.

FIGURE 2.1
Percentage of taxa surveyed and inventoried by countries under the different use groups



Notes: * Including fruit plants, vegetables, roots and tubers, herb and spices, pulses, cereals, oil plants, pseudo cereals and nuts. **Including plants used for other purposes, including research, sweeteners, fibres and stimulants. Based on 80 country reports.

2.3.1 Inventory and state of knowledge of crop wild relatives and wild food plants

About 2 200 *in situ* surveys focusing on CWR and WFP were undertaken during the 2012–2019 period by a total of 71 countries. Figure 2.2 depicts the geographic distribution of countries reporting on surveys and inventories of wild PGRFA. These countries are listed by region in Table 2.1.

Countries identified populations of 1 285 taxa of wild PGRFA belonging to 89 botanical families. *Fabaceae, Poaceae, Solanaceae, Convolvulaceae* and *Rosaceae* were the five most represented families, and accounted for 58 percent of the total surveyed diversity.

Overall, 35 percent of the wild PGRFA surveyed were reported to be threatened in at least one survey. These figures indicate a high level of risk for wild PGRFA.

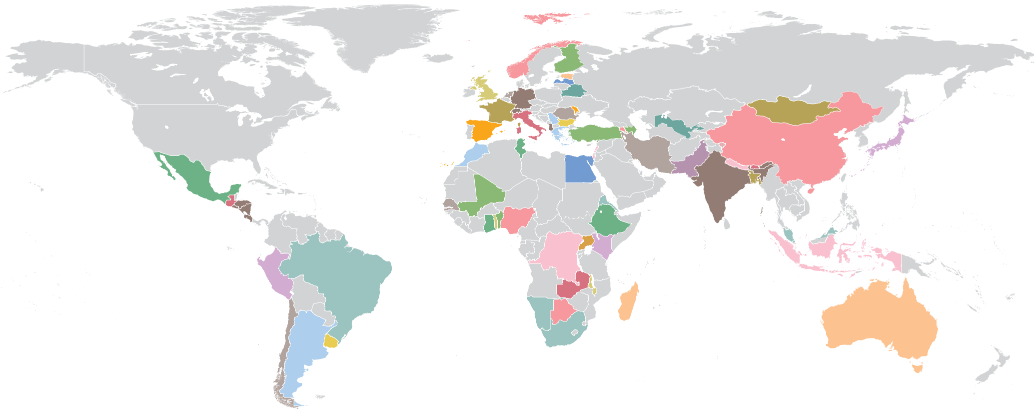
Crop wild relatives

CWR belonging to 1 050 taxa from 142 genera were surveyed in 66 countries (Table 2.2); 169 of these taxa were also considered to be WFP. The most frequently surveyed genera of CWR by region were:

- Northern Africa: *Daucus, Chenopodium* and *Medicago*;
- Sub-Saharan Africa: *Dioscorea, Cenchrus* and *Oryza*;
- Latin America and the Caribbean: *Solanum, Ipomoea, Phaseolus, Prunus, Helianthus, Persea, Manihot* and *Gossypium*;
- Asia: *Trifolium, Aegilops, Solanum, Vicia, Lathyrus, Medicago, Allium, Hordeum, Lactuca, Mangifera, Piper* and *Prunus*; and
- Europe: *Trifolium, Vicia, Lathyrus, Allium* and *Medicago*.

FIGURE 2.2

Countries reporting on surveys and inventories of wild plant genetic resources for food and agriculture



Notes: The names of the countries are provided in Table 2.1. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 71 country reports.

TABLE 2.1

Countries where surveys of crop wild relatives and wild food plants were undertaken between 2012 and 2019

Region *(number of countries)*	Countries
Northern Africa *(3)*	Egypt, Morocco, Tunisia.
Sub-Saharan Africa *(18)*	Benin, Botswana,* Democratic Republic of the Congo, Eritrea, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Namibia, Niger, Nigeria, Senegal, South Africa,* Togo, Uganda, Zambia.
Latin America and the Caribbean *(12)*	Argentina, Brazil, Chile, Costa Rica, Cuba, Ecuador,* El Salvador, Guatemala, Mexico, Nicaragua, Peru, Uruguay.
Oceania *(1)*	Australia
Asia *(19)*	Armenia, Azerbaijan, Bangladesh, Bhutan, China, India, Indonesia, Iran (Islamic Republic of), Japan, Jordan, Kyrgyzstan, Lebanon, Malaysia, Mongolia, Nepal, Pakistan, Tajikistan, Türkiye, Uzbekistan.
Europe *(18)*	Albania, Bulgaria, Belarus, Germany, Estonia, Finland, France, Greece, Italy, Latvia, Netherlands (Kingdom of the), Norway, Republic of Moldova, Romania, Serbia, Spain, Switzerland, United Kingdom.

Note: *Information provided through the narrative report only.

TABLE 2.2
Numbers of reporting countries, surveys undertaken and crop wild relatives taxa surveyed, by region

Region	Number of		
	Countries	Surveys	CWR taxa
Northern Africa	3	36	34
Sub-Saharan Africa	16	90	65
Latin America and the Caribbean	11	443	350
Oceania	1	91	90
Asia	17	516	363
Europe	18	894	353
Total	**66**	**2 070**	**1 050**

Note: CWR = crop wild relatives.

Countries from Asia, Europe and Latin America and the Caribbean surveyed over one-third of the total taxa reported for this group of plants. The largest number of CWR surveys were undertaken in Europe, with 894 surveys conducted in 18 countries, followed by Asia, and Latin America and the Caribbean.

About one-third (35 percent) of the CWR surveyed were reported as threatened in at least one survey.[3] Figure 2.3 shows the percentage of inventoried CWR found to be threatened by region. The larger the pie chart, the larger the number of CWR inventoried.

Over 65 percent of CWR taxa surveyed in Africa, where a relatively low number of taxa were surveyed, were found to be threatened at least once. Conversely, in Asia, Europe and Latin America and the Caribbean, where more CWR were surveyed, the proportion of threatened taxa ranged from 19 percent to 38 percent. In Australia, where mainly forages were surveyed, only 1 percent were reported to be threatened at least once.

In addition to those covered in the above analysis, a number of other diverse initiatives that assessed the conservation status of CWR were undertaken at global, regional and national levels during the reporting period:

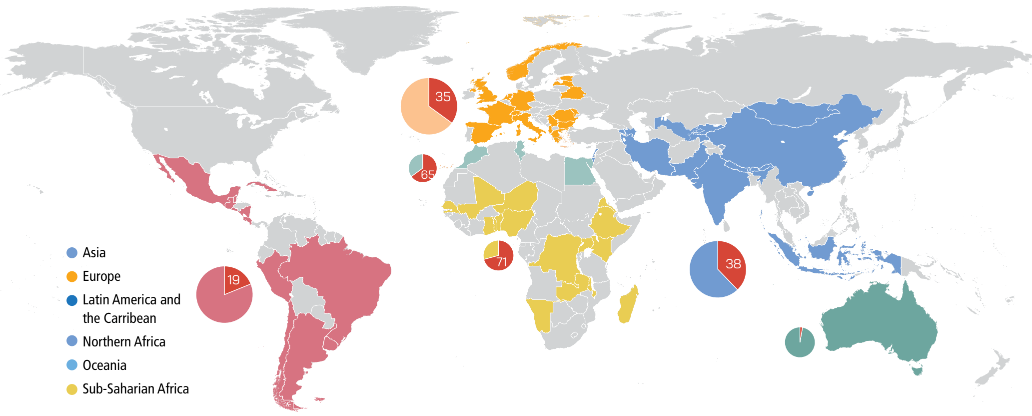
- The Southern African Development Community (SADC) countries[4] collaborated in a project on the *in situ* conservation of CWR that resulted in an inventory of 1 900 priority CWR (Allen *et al*., 2019);
- In Europe,[5] a European CWR priority list of 863 taxa related to human and animal food crops was developed, and an *in situ* database of population occurrences with georeferenced data was generated for Europe and Türkiye (Rubio Teso *et al*., 2021);
- In Mesoamerica, a list of about 3 000 CWR was compiled, including 310 priority species from Mexico, 105 taxa from Guatemala, 50 taxa from El Salvador and 54 taxa from Honduras (Contreras-Toledo *et al*., 2018; Goettsch *et al*., 2021);
- In Nicaragua, ethnobotanical studies documented 293 species of wild and domestic flora used by Indigenous Peoples and local communities (Miskito, Mayagna and Branches) (Nicaragua country report);

3 Threatened taxa are those that are no longer found *in situ* at the sites where they were previously found.

4 Further information at http://www.cropwildrelatives.org/sadc-cwr-project/; and http://www.cropwildrelatives.org/sadc-cwr-net.

5 Further information at http://www.farmerspride.eu

FIGURE 2.3
Regional percentages of crop wild relatives taxa identified as threatened in at least one *in situ* survey reported by countries



Notes: The size of the pie charts is proportional to the total number of crop wild relatives taxa surveyed. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 71 country reports.

- An assessment of the *in situ* conservation status of the CWR of potato, yam, groundnut and millet was undertaken by the Global Crop Diversity Trust (Crop Trust) as part of an in-depth review of conservation strategies for these crops (Crop Trust, 2022).

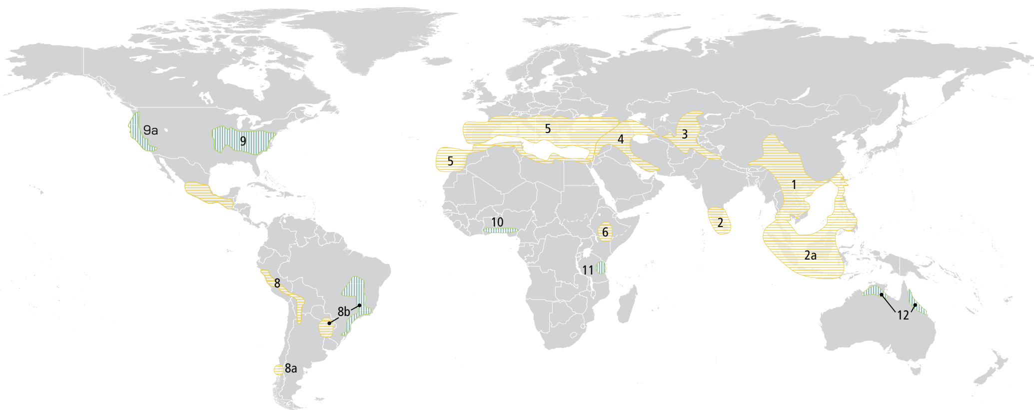
A global inventory of over 1 000 priority CWR from 173 crops important for global food security was undertaken by the University of Birmingham, the Crop Trust and the Millennium Seed Bank of the Royal Botanic Gardens, Kew (Vincent *et al*., 2013). The study highlighted the high concentrations of CWR species present in Western Asia, China and Southeastern Europe. An ecogeographic dataset was used to identify the top 100 sites where genetic reserves could be established within protected areas globally, as well as a further 50 *in situ* sites outside protected areas (Vincent *et al*., 2019). The same dataset was used to review the correlation between CWR distribution and the eight Vavilov centres of diversity (Vavilov, 1926), and resulted in the addition of four centres to the existing list (Figure 2.4), including in the western seaboard, eastern seaboard and great plains of the United States of America, coastal and central Brazil, the coast of Southwest Africa, the coast of the United Republic of Tanzania, and northern Australia (Maxted and Vincent, 2021).

Wild food plants

Surveys of WFP representing 405 taxa from 192 genera were reported by 54 countries. About 38 percent of all these taxa were found to be threatened by at least one of the surveys.The percentages of the surveyed taxa found to be threatened are shown by region in the pie charts of Figure 2.5; the larger the pie chart, the larger the number of WFP taxa surveyed.

The percentages of surveyed WFP taxa found to be threatened in the various regions of the world show a similar pattern to the equivalent figures for CWR. Latin America and the Caribbean had the lowest percentage of threatened WFP taxa, out of a relatively high number inventoried

FIGURE 2.4
Revised Vavilov centres of diversity



Revised Vavilov centres of diversity and the countries and geographical areas associated with them. The areas in orange are the original centres. The areas in green indicate the additions.

1. Chinese (China, Viet Nam, Lao People's Democratic Republic and Cambodia)
2. Indian (India and Sri Lanka)

2a. Indo-Malayan (Thailand, Malaysia, Indonesia and the Philippines)

3. Central Asian (Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan)
4. Near Eastern (Türkiye, Transcaucasia, Turkmenistan and the Islamic Republic of Iran)
5. Mediterranean (countries bordering the Mediterranean Sea)
6. Abyssinian (Ethiopia)
7. Mesoamerican (Mexico and Guatemala)
8. South American (Peru, Ecuador and the Plurinational State of Bolivia)
   8a. Chiloe, Chile
   8b. Brazil and Paraguayan (Brazil and Paraguay)
9. Western and Eastern United States of America (United States of America)
10. Coastal West African (Ghana, Togo, Benin, Nigeria and Cameroon)
11. East African (United Republic of Tanzania and Kenya)
12. Northern Australian (Australia)

Notes: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.

Source: Reproduced with permission from Maxted, N. & Vincent, H. 2021. Review of congruence between global crop wild relative hotspots and centres of crop origin / diversity. *Genetic Resources and Crop Evolution*, 68(4): 1283–1297. https://doi.org/10.1007/s10722-021-01114-7

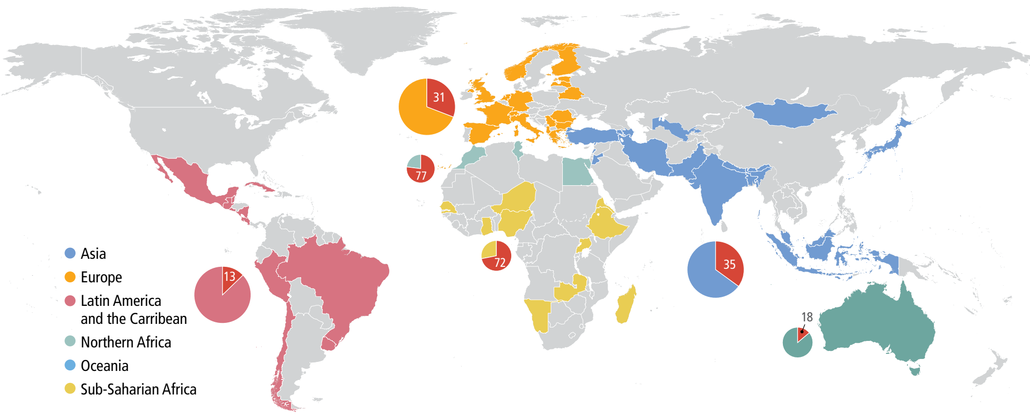
(109 distinct taxa), followed by Oceania. The highest percentage was again in Africa, where only 36 taxa were surveyed.

The most commonly surveyed genera of WFP were *Solanum, Allium, Physalis, Chenopodium, Rumex, Fragaria, Vaccinium* and *Lactuca*. The WFP surveyed in the largest number of countries included wild strawberry (*Fragaria vesca*) in ten countries, prickly lettuce *(Lactuca serriola*) in eight countries, crab apple *(Malus sylvestris*) in eight countries, wild radish *(Raphanus raphanistrum*) in seven countries and bilberry (*Vaccinium myrtillus*) in six countries. The genera with the highest numbers of threatened species included *Allium* (13 species), *Solanum* (six species), *Prunus* (five species) and *Chenopodium* (five species). The WFP reported to be under threat by the largest number of countries were *Persea schiedeana* (four countries in Central America), *Malus sylvestris* (three countries in Europe) and *Origanum syriacum* (three countries in Western Asia and Northern Africa).

Countries also provided information on WFP, including those conserved *in situ*, for

FIGURE 2.5

Regional percentages of wild food plants taxa identified as threatened in at least one *in situ* survey reported by countries



Notes: The size of the pie charts is proportional to the total number of wild food plants taxa surveyed. The red segments of the pies indicate the proportion of taxa identified as threatened. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 54 country reports.

the preparation of *The State of the World's Biodiversity for Food and Agriculture*. A total of 91 countries listed 1 955 wild plant species used as food, of which 150 species were reported to be conserved *in situ* (FAO, 2019b). Box 2.1 presents a case study of WFP surveyed in Togo.

Awareness of the importance of WFP and the number of initiatives focusing on them have increased over the reporting period, although not to the same extent as for CWR. Key initiatives include the following:

- the Useful Plants Project[6] identified 615 species of WFP by working with local communities across five countries (Botswana, Kenya, Mali, Mexico and South Africa);
- a comprehensive study on wild PGRFA that was conducted by a consortium of scientists led by the Royal Botanic Gardens, Kew recorded 7 039 edible plant species, defined as species with "human food" use, some of which are both CWR and WFP (Ulian *et al.*, 2020; Antonelli *et al.*, 2020); and
- the Biodiversity for Food and Nutrition project[7] that identified 42 wild edible plants in Türkiye and prioritized them for further research (Hunter *et al.*, 2019); it also compiled a list of 246 wild plant species used as food in Morocco (Nassif and Tanji, 2013).

Several studies have reviewed and documented the use and diversity of WFP in specific geographical areas, including:

- 291 WFP taxa in the Catalan Linguistic Area (Gras *et al.*, 2021);
- 106 WFP taxa of 85 species in West Sumatra (Pawera *et al.*, 2020);

[6] Further information at https://www.kew.org/science/our-science/projects/project-mgu-useful-plants-project#:~:text=Since percent202007 percent2C percent20the percent20Project percent20MGU,are percent20important percent20to percent20local percent20communities

[7] Further information at http://www.b4fn.org

TABLE 2.3

Numbers of reporting countries, surveys undertaken and wild food plants taxa surveyed, by region

Region	Number of		
	Countries	Surveys	CWR taxa
Northern Africa	2	32	31
Sub-Saharan Africa	10	45	36
Latin America and the Caribbean	10	166	109
Oceania	1	37	37
Asia	15	167	137
Europe	16	233	114
Total	**54**	**680**	**405**

Note: WFP = wild food plants.

Box 2.1

Surveying wild food plants in Togo

Recognizing the vital role of wild food plants in people's diets, an inventory of non-timber forest products was conducted in Togo in 2017. The study identified 87 wild species producing edible fruits consumed by local communities and 16 species for which leaves, fruits and seeds were all used in the diets of both rural and urban populations.

The following species were found to be harvested for their seeds: *Blighia sapida, Borassus aethiopium, Borassus akeassi, Garcinia kola, Cola nitida, Cola millenii, Cola gigantea, Vitellaria paradoxa, Pentadesma butyracea, Parkia biglobosa, Adansonia digitata, Bombax costatum, Moringa oleifera* and *Elaeis guineensis*. Species used for their sap and for winemaking (*Elaeis guineensis*, Raphia spp.) were also identified. Some species, notably *Vitellaria paradoxa, Xylopia aethiopica* and *Monodora myristica*, were found to be of considerable economic importance, as they are traded internationally. During the period between 2016 and 2018, about 100 species of medicinal plants were also surveyed and documented.

Source: Data provided by Togo.

- 40 WFP taxa in two valleys in northern Pakistan (Aziz *et al*., 2020);
- 70 WFP taxa in the northwest of the Russian Federation (Kolosova *et al*., 2020);
- 31 WFP taxa of fruits species in the Mpumalanga province of South Africa (Shai *et al*., 2020); and
- 1 403 WFP species from 184 families in India (Ray *et al*., 2020).

2.3.2 *In situ* conservation sites of wild plant genetic resources for food and agriculture

During the reporting period, protected *in situ* conservation sites increased in area by 16 percent to almost 13 million km^2 in 59 reporting countries. At the global level, there was an increase of 11 percent, to a total of 22.4 million km^2 (UNEP-WCMC and IUCN. 2022). Conservation sites are often under considerable pressure from climate change, invasive species, overharvesting and other threats that lead to the degradation of ecosystems and declines in species richness (IPBES, 2019a). The development and implementation of management plans, targeting wild PGRFA, for conservation sites and their periodic monitoring are therefore essential for the effective conservation of these resources *in situ*.

Overall, there is still little evidence that populations of CWR and WFP are actively conserved

TABLE 2.4

Number of *in situ* conservation sites and proportion with management plans for wild plant genetic resources for food and agriculture, by region

Region (No. of reporting countries)	No. of conservation sites	Percentage of sites with management plans for wild PGRFA
Northern Africa *(3)*	139	19
Sub-Saharan Africa *(18)*	3 851	8
Latin America and the Caribbean *(13)*	1 072	29
Oceania *(1)*	10 500	0
Asia *(15)*	2 311	7
Europe *(19)*	39 569	7
Total/average *(69)*	**57 442**	**6**

Note: PGRFA = plant genetic resources for food and agriculture.

in situ. Data provided by the 69 countries that reported on this topic show that only 6 percent of *in situ* conservation sites have management plans that specifically address CWR and WFP conservation. Among regions, Latin America and the Caribbean has the highest coverage (29 percent of sites), followed by Northern Africa (19 percent), and Asia and Europe (7 percent in both cases) (Table 2.4). Although Oceania (specifically Australia) reported over 10 000 *in situ* conservation sites, none of these have any management plans that address wild PGRFA conservation and management. In interpreting these figures it should be borne in mind that countries may have had difficulty assembling and reviewing the management plans for all their *in situ* conservation sites.

Various sites around the world are used for the *in situ* conservation of biodiversity in general. These include Important Plant Areas (Anderson, 2002), Key Biodiversity Areas (IUCN, 2016), and Man and the Biosphere sites of the United Nations Educational, Scientific and Cultural Organization (UNESCO).[8] Although such sites do not specifically target CWR and WFP, they include areas where these groups of plants may grow. Box 2.2 provides an example from Kyrgyzstan, where the Community Conservation Research Network maintains a number of protected areas, including the Issyk-Kul Biosphere Reserve. More recently, the International Union for Conservation of Nature (IUCN) has implemented OECMs, which include an array of further sites where CWR and WFP (as well as FV/LR) are conserved (IUCN, 2019). The number of OECMs has increased significantly since 2019, although it should be noted that at least part of this increase is a result of a larger number of countries reporting on their OECMs over the period since reporting started (Figure 2.6).

2.3.3 Programmes and projects on *in situ* conservation of crop wild relatives and wild food plants

A total of 68 countries (Figure 2.7) reported 427 programmes implemented over the reporting period that directly related to *in situ* conservation of CWR and WFP. Six countries implemented more than ten *in situ* programmes, while most (45 countries) implemented between one and five. More programmes specifically targeted CWR (40 percent) than WFP (22 percent). Another 26 percent focused on both groups. The remaining programmes addressed CWR and/or WFP only marginally.

Countries also indicated how many of their *in situ* programmes that implement management practices aimed at maintaining

[8] Further information at https://en.unesco.org/mab

Box 2.2

In situ conservation of wild plant genetic resources for food and agriculture in Kyrgyzstan

In Kyrgyzstan, the Community Conservation Research Network, a network of protected areas, currently covers 7 percent of the country's area and includes ten state nature reserves (509 900 ha), 13 state natural parks (724 900 ha), 64 reserves (including integrated, botanical, zoological and forest areas totalling 241 500 ha) and one biosphere territory (4 314 400 ha).

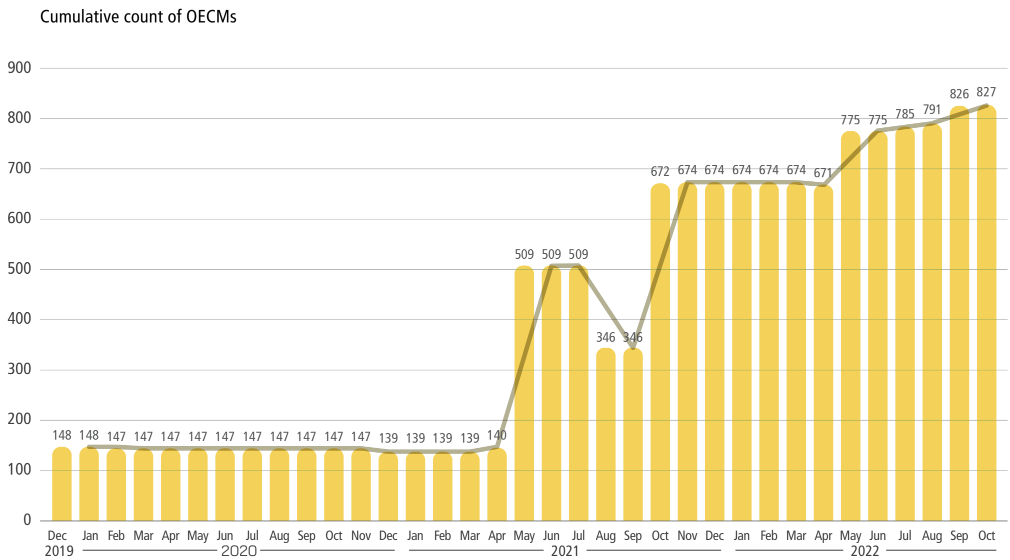
In 2012, the Dashman Nature Reserve was established to address the conservation of wild walnut (Juglans regia) as a particularly valuable tree species. The wild walnut is also protected in the state biosphere reserve of Sary-Chelek, the purpose of which is to protect the unique walnut–fruit forests. In 2016, Sary-Chelek and the state nature reserves of Besh-Aral and Padyshata, as part of the transnational (transboundary) category Western Tien Shan (prepared jointly by Kyrgyzstan, Kazakhstan and Uzbekistan), were included in the list of Natural World Heritage Sites of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

In addition to wild walnut, 11 species of wild food plants and crop wild relatives listed in the Red Book of Kyrgyzstan are actively conserved: twelve-dentate onion (*Allium dodecadontum*), pskem onion (*Allium pskemense*), Semenov's onion (*Allium semenovii*), Kashgarian barberry (*Berberis kaschgarica*), Central Asian pear (Pyrus asiae-mediae), Korzhinski's pear (*Pyrus korshinskyi*), Niedzvetzki's apple (*Malus niedzwetzkyan*a), Sievers's apple (*Malus sieversii*), Knorring's hawthorn (*Crataegus knorringian*a), Petunnikov's almond (*Amygdalus petunnikowii*) and Uzunakhmat grape (*Vitis usunachmatica*).

Source: Data provided by Kyrgyzstan.

FIGURE 2.6

Cumulative number of other effective area-based conservation measures from December 2019 to October 2022

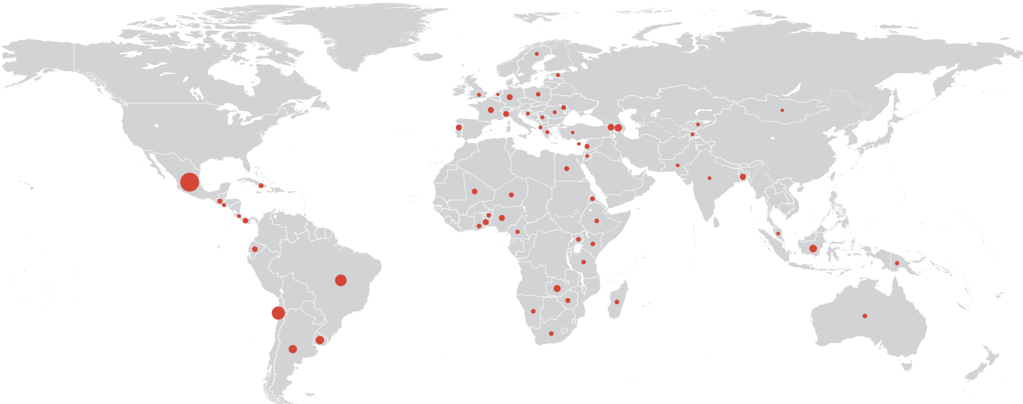


Notes: The line shows the trend in the average number of other effective area-based conservation measures (OECMs) through time. The counts include all OECMs, whether or not they are of particular significance to the conservation of plant genetic resources for food and agriculture.

Source: UNEP-WCMC & IUCN. 2022. *Protected Planet: World Database on Other Effective Area-Based Conservation Measures.* [Cited 15 October 2022]. www.protectedplanet.net

FIGURE 2.7

Number of programmes on *in situ* conservation of crop wild relatives and wild food plants, by country



Notes: The size of the circles is proportional to the number of programmes implemented. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 68 country reports.

TABLE 2.5

Topics covered in the implementation of *in situ* conservation programmes

Topic	Number of programmes	Number of countries
Implementation of management practices to maintain a high level of genetic diversity	239	43
Arrangements for *ex situ* conservation of threatened and endangered populations	144	42
Involvement of local communities	207	42
Implementation of plans to encourage public participation	101	31

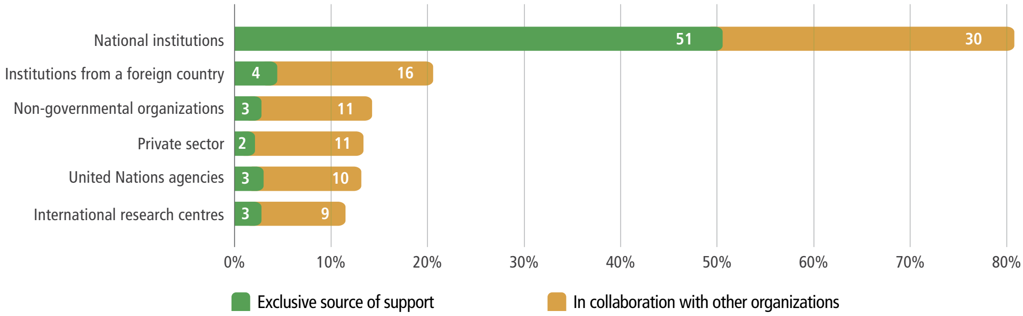
Note: Based on 68 country reports.

high levels of genetic diversity involve local communities, make arrangements for *ex situ* conservation of threatened and endangered populations and/or have plans for encouraging public participation. Most countries have implemented more than one such programme (Table 2.5).

Support for the implementation of *in situ* programmes was provided by various, often multiple, sources (Figure 2.8). The large majority of programmes were supported by national institutions (81 percent), either exclusively (51 percent) or in collaboration with other organizations (30 percent). Support also came from institutions from foreign countries (20 percent of programmes), non-governmental organizations (NGOs) (14 percent), the private sector (13 percent), UN agencies (13 percent) and international research centres (12 percent).

Almost half these programmes (198) were undertaken in 14 countries from Latin America and the Caribbean. Of these, Mexico, Chile and Brazil

FIGURE 2.8
Percentage of programmes on *in situ* conservation of crop wild relatives and wild food plants supported by different stakeholder categories



Note: Based on 68 country reports.

had the largest number of projects implemented over the reporting period (Figure 2.7).

During the 2012–2019 period, FAO's Technical Cooperation Programme projects supported 14 countries in sub-Saharan Africa[9] with the development of national strategies for the conservation and sustainable use of PGRFA. Other actions undertaken during this period included the Government of the United Kingdom of Great Britain and Northern Ireland's Darwin Initiative project "Bridging agriculture and environment: Southern African crop-wild-relative regional network"[10] which assessed the diversity of CWR in the SADC region and identified priority protected areas with the highest *in situ* CWR species diversity (Magos-Brehm *et al*., 2022). Under this project, Malawi and the United Republic of Tanzania established genetic reserves for the *in situ* conservation of CWR in at least two national protected areas respectively. In addition to the above initiatives, Mauritius, South Africa, Tunisia and Zambia prepared National Protected Areas Expansion Strategies (NPAES) that aim to include high priority areas for CWR in the countries' networks of protected areas. Along with their NPAES, these countries have also established policies and legislation governing these areas. For example, in South Africa, the 2016 NPAES includes ten CWR priority sites, and an additional 46 priority sites were planned to be included in the 2024 NPAES.

In Europe, as part of the Farmer's Pride project,[11] sites containing priority CWR have been mapped with the aim of developing a systematic approach to the conservation of CWR in the region (Box 2.3).

2.3.4 Summary assessment

The number of surveys reported by countries has risen considerably compared to the number reported under previous global assessments. For the SoW1, four countries reported on surveying and inventorying activities, while 28 countries reported on this for the SoW2 and 66 countries for the SoW3.

According to the data provided for the current report, about one-third of CWR and WFP surveyed during the reporting period were found to be threatened. Despite the large expansion of terrestrial protected areas, from 20.2 million km^2 in 2012 to 22.4 million km^2 in 2019, a large majority (about 94 percent) of *in situ* conservation sites,[12] including protected areas, were reported

[9] Angola, Burundi, Eswatini, Ethiopia, Kenya, Madagascar, Malawi, Namibia, Rwanda, Somalia, South Sudan, Uganda, United Republic of Tanzania, Zimbabwe.

[10] Further information at https://www.darwininitiative.org.uk/project/DAR26023/

[11] Further information at https://more.bham.ac.uk/farmerspride

[12] A national *in situ* conservation site is defined as a protected area where crop wild relatives and/or wild food plants occur.

Box 2.3

Potential of the Natura 2000 network for *in situ* conservation of crop wild relatives

Europe has an extensive network of protected areas established under the Natura 2000 network, the largest network of protected areas in the world, with approximately 26 000 sites stretching across all 27 European Union countries and the United Kingdom of Great Britain and Northern Ireland, both on land and at sea. It is also one of the most important instruments of the European Union's policy for the conservation of biodiversity. The Farmer's Pride Horizon 2020 project assessed the potential of the Natura 2000 network of protected areas in Europe to secure crop wild relatives (CWR) diversity *in situ*, and it concluded that it was significant: 31 percent of the sites in the network included at least 519 taxa (Rubio Teso *et al.*, 2020). The project also developed a tool[a] that managers of these areas can use to identify which CWR are found in Natura 2000 protected areas, and guidelines on how to manage CWR populations *in situ* (Iriondo *et al.*, eds., 2021). Finland, France and the United Kingdom have reported the number of Natura 2000 sites specifically targeting the maintenance of CWR species.

Sources: Rubio Teso, M.L., Álvarez Muñiz, C., Gaisberger, H., Kell, S., Lara-Romero, C., Magos-Brehm, J., Maxted, N. & Iriondo, J. 2020. Crop wild relatives in Natura 2000 network. Birmingham, UK, University of Birmingham. https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/10/MS19_Crop_Wild_Relatives_in_the_Natura_2000_Network.pdf and Iriondo, J.M., Magos Brehm, J., Dulloo, M.E. & Maxted, N. eds. 2021. Crop Wild Relative Population Management Guidelines. Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources. Birmingham, UK, University of Birmingham. http://www.farmerspride.eu/

[a] Further information at https://www.ecpgr.cgiar.org/crop-wild-relatives-in-natura-2000

still not to have management plans specifically targeting CWR and WFP.

Since many of these conservation sites fall within the purview of ministries of forestry or the environment, many countries stressed the need for increased cooperation among relevant institutions under the different ministries involved. The reported decrease in the expert capacity needed for the identification and monitoring of PGRFA in the wild, including in botanical taxonomy, is a further constraint to the effective conservation and management of wild PGRFA.

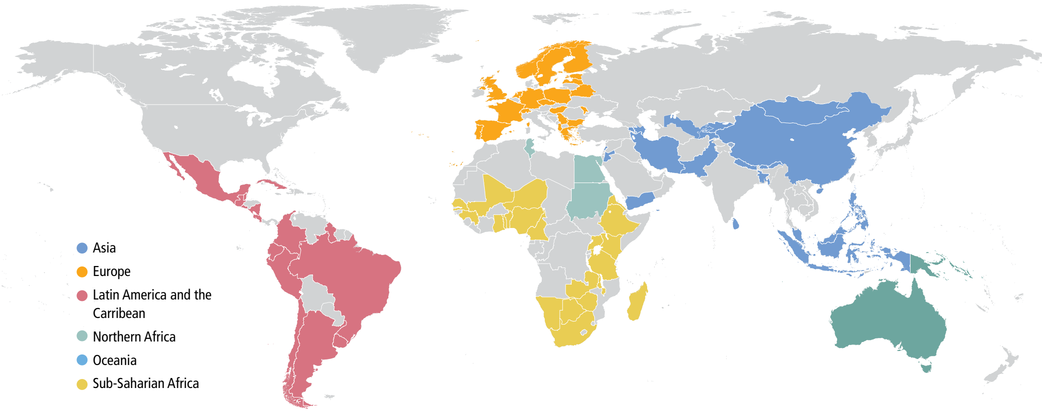
Support for *in situ* conservation programmes for wild PGRFA during the reporting period was provided mainly by national institutions, either as the sole source of support or in collaboration with others. They are considered to play a critical role because of their support for activities such as surveying, implementing conservation measures, awareness raising and fostering policy development. Efforts should, however, be made to increase the involvement of other stakeholders who have the potential to contribute.

2.4 On-farm management and improvement of plant genetic resources for food and agriculture

FV/LR result from natural and human-managed selection and include populations of cultivated species that are often highly genetically diverse, heterogeneous and adapted to local environments (FAO, 2019a; IPBES, 2019a). As such, they may possess valuable traits for breeding new varieties adapted to changing climatic scenarios. Their management on farm is important to the livelihoods of many farmers around the world and contributes to the supply of ecosystem services.

Countries reported an increase in the number of programmes, projects and activities addressing the on-farm conservation and management of FV/LR over the reporting period, totalling 1 138 initiatives in 81 countries (Figure 2.9). These were mainly carried out with public and private funding by public-sector organizations (national genebanks, research institutes and universities), private-sector organizations (seed companies and private foundations) and civil society

FIGURE 2.9
Countries reporting programmes or projects addressing on-farm management and improvement of plant genetic resources for food and agriculture



Note: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 81 country reports.

organizations (NGOs, seed networks, farmers associations). However, most of the activities that support on-farm management globally have involved pilot, project-based studies and have tended to be short-term initiatives.

The most frequently reported activities undertaken by countries through programmes and projects addressing on-farm management and improvement of PGRFA were:

- characterization and evaluation of local varieties: 53 percent;
- assessment of the utilization and management of local varieties: 47 percent;
- assessment of farmers' knowledge: 43 percent;
- seed multiplication and distribution of improved local varieties: 42 percent;
- on-farm breeding: 34 percent; and
- assessment of the utilization and management of improved varieties: 32 percent.

Data from 69 countries on the support provided for on-farm management and breeding provides useful information on the numbers of farmers involved in these activities, the percentage of land cultivated with FV/LR, and the numbers of FV/LR returned to farmers from national or local genebanks (either directly or through intermediaries).

Since 2012, recognition of the role of farmers in managing local crop diversity (mainly FV/LR) has increased in many countries. Many donors increasingly require the participation of Indigenous Peoples and local communities and/or the implementation of participatory approaches.

The role that farmers play in managing FV/LR is illustrated in Box 2.4, which describes the management of potato diversity in Peru, highlighting interactions among a diverse range of stakeholders and the resulting improvements to livelihood and to the conservation and use of FV/LR.

2.4.1 Surveying and inventorying of farmers' varieties/landraces

During the reporting period, advances were made in the surveying and inventorying of FV/LR to improve knowledge of their diversity and distribution in farming systems. Countries report that most of the inventories were carried out

Box 2.4

Multistakeholder initiatives for the conservation and use of potato landraces in Peru

The Potato Park Peru, a reserve of more than 15 000 ha located in the Andean region of Cusco, is a conservation initiative led by local stakeholders and established in early 2000 by six Indigenous Quechua communities in the Sacred Valley of the Incas. Focusing on the potato as a cultural symbol, the Potato Park has successfully promoted the conservation and use of the almost 1 400 potato varieties maintained by local communities (FAO, 2022). In partnership with the Asociación ANDES, Asociación del Parque de la Papa and the International Potato Center (CIP), farmers have produced seed potatoes from their traditional cultivars. These cultivars are also safety duplicated in the Svalbard Global Seed Vault for long-term conservation. CIP has also been conserving potato landraces and working with farmers to repatriate these genetic resources upon their request since 1997 (de Haan, 2021). As of 2020, 135 communities had received 14 950 samples (1 519 accessions) of cultivated potato from CIP's genebank (Lüttringhaus et al., 2021). In March 2020, the Potato Park was recognized as an agrobiodiversity zone by Peru's Ministry of Agrarian Development and Irrigation (MIDAGRI) through Ministerial Resolution No. 0081-2020-MIDAGRI.

Through another initiative, the farmer-led Association of Potato Guardians or AGUAPAN[a] has worked with local farmers from different regions to promote knowledge exchange. The association also provides direct monetary payments to its members, currently representing over 100 communities, through direct agreements with the private sector. Each member is a locally recognized household maintaining at least 50 potato landraces. AGUAPAN has created a collective brand called Miski Papa,[b] which offers a high value market for its members. It is estimated that the association conserves around 1 500 unique landraces. A recent genetic study of the landrace pools of AGUAPAN members documented 88 landraces that were not yet held in genebanks.

Sources: De Haan, S. 2021. Community-based conservation of crop genetic resources. In: E. Dulloo, ed. *Plant genetic resources: a review of current research and future needs*, 229–249. Cambridge, UK, Burleigh Dodds Science Publishing; FAO. 2022. *Proceedings of the First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture: Technical consultation on in situ conservation and on-farm management of plant genetic resources for food and agriculture* – 29–30 March 2021, Rome. https://doi.org/10.4060/cc3716en; and Lüttringhaus, S., Pradel, W., Suarez, V., Manrique-Carpintero, N.C., Anglin, N.L., Ellis, D., Hareau, G., Jamora, N., Smale, M. & Gómez, R. 2021. Dynamic guardianship of potato landraces by Andean communities and the genebank of the International Potato Center. *CABI Agriculture and Bioscience*, 2: 45. https://doi.org/10.1186/s43170-021-00065-4

[a] Further information at https://aguapan.org

[b] Further information at https://aguapan.org/en/que-es-miskipapa/

within the framework of ongoing programmes and projects involving diverse stakeholders, including those from the public sector (national genebanks, research institutes, universities) private sector (seed companies and associations) and civil society, with a focus on specific geographical areas. A total of 71 countries reported that almost 105 000 FV/LR from about 1 300 crops were surveyed/inventoried during the reporting period. Table 2.6 presents the number of FV/LR surveyed/inventoried by subregion, and the percentage of these found to be threatened.

Overall, about 6 percent of the FV/LR surveyed were found to be threatened. High incidences of threatened FV/LR were reported in Northern Africa, Latin America and the Caribbean, and sub-Saharan Africa (Figure 2.10), and at the subregional level in Southern Africa, the Caribbean and Western Asia (Table 2.6).

Given the scale of the operations required, systematic on-farm surveys and assessments of FV/LR are difficult and costly to implement. Although the importance of inventories and assessment of FV/LR is globally recognized, the capacity of countries to perform comprehensive assessments that cover cultivated diversity at the national level rather than at the provincial, district or site level is constrained by a lack of human and financial resources. The reported activities were carried out within the framework

TABLE 2.6

Number of reporting countries, crops, farmers' varieties/landraces surveyed, and percentage of farmers' varieties/landraces found to be threatened, by subregion

Subregion	Countries (No.)	Crops surveyed (No.)	FV/LR surveyed (No.)	FV/LR threatened (%)
Northern Africa	2	15	1 021	26
Eastern Africa	8	57	1 936	6
Southern Africa	2	16	177	42
Middle Africa	2	23	212	29
Western Africa	7	104	9 738	18
Central America	5	81	2 846	8
Caribbean	2	165	808	40
South America	8	150	5 638	18
Australia and New Zealand	1	172	219	1
Central Asia	3	12	165	36
Eastern Asia	2	32	41 864	-
South-eastern Asia	3	204	7 133	7
Southern Asia	5	113	16 943	1
Western Asia	5	66	1 294	40
Northern Europe	3	16	1 795	3
Eastern Europe	4	540	6 415	3
Southern Europe	6	80	2 041	7
Western Europe	3	98	4 741	18
Total/average	**71**	**1 276**	**104 986**	**6**

Note: FV/LV = farmers' varieties/landraces.

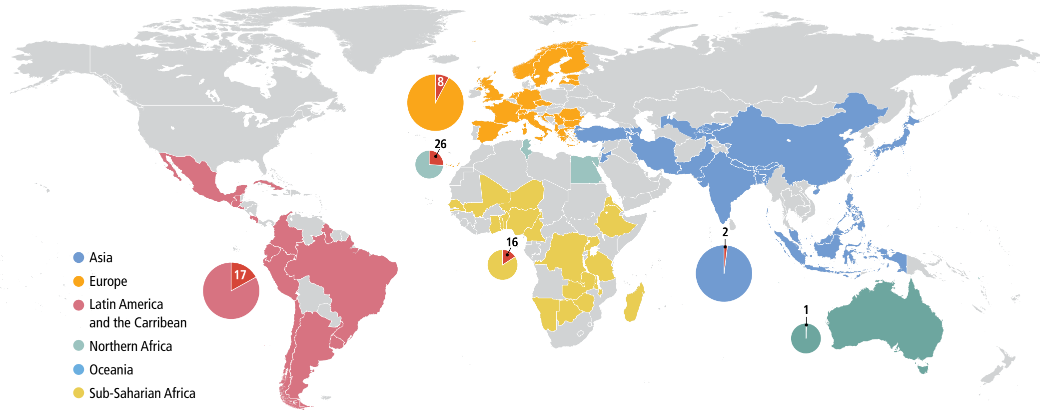
of research projects that had limited geographical coverage and were often limited to single points in time. An analysis of trends was thus precluded.

2.4.2 Farmers' varieties/landrace diversity and area of cultivation

Farmers continued to maintain and improve a significant amount of locally adapted FV/LR genetic diversity on farm. In the 51 countries that provided information on this, about 35 million ha, equivalent to 44 percent of the total crop area of reported sites within areas of high diversity (~80 million ha), were cultivated with FV/LR. This entailed over 160 crops and 60 mixed crop groups at over 403 localities globally.

Cereals had the largest area under FV/LR cultivation (21.7 million ha), which accounted for 43 percent of the total area under this crop group at over 130 reported sites, and 32 percent of the total reported area planted with FV/LR. Maize, sorghum, teff, pearl millet, rice and wheat were among the cereals most represented in this total, with their areas of cultivation under FV/LR ranging from 4.8 million ha at 36 sites in 21 countries to 1.6 million ha at 17 sites in ten countries. Figures above 21 percent for the proportion of the corresponding total crop area planted with FV/LR were reported for pulses (22 percent), vegetables (22 percent), root and tuber crops (35 percent), forages (56 percent), oil plants (80 percent) and stimulant crops (mainly coffee) (80 percent).

FIGURE 2.10
Regional percentages of farmers' varieties/landraces identified as threatened in at least one *in situ* survey reported by countries



Note: The size of the pie charts is proportional to the number of farmers' varieties/landraces surveyed. The red segments indicate the proportion found to be threatened. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 71 country reports.

A detailed analysis was undertaken for ten countries[13] to assess the variation over time (2012–2014 versus 2014–2019) of the share of FV/LR cultivation at 39 site[14] for 28 crops and six crop groups (Table 2.7). In most of the countries, there was a decrease overall in the proportion of crop area under FV/LR. Of note are the 26 percent increases in the figures for vegetable FV/LR in Nepal and the 25 percent decrease for peach FV/LR in Azerbaijan.

2.4.3 Distribution of farmers' varieties/landraces to farmers from national and local genebanks

The number of samples of FV/LR distributed during the reporting period by national or local genebanks to farmers was 58 323, representing 1.5 percent of the germplasm exchanged over the period and documented by countries (4.2 million samples). FV/LR of cereals were the most commonly distributed (reported by 52 countries), followed by pulses (reported by 48 countries), vegetables (reported by 45 countries), fruits (26 countries) and roots/tubers (25 countries).

Samples of FV/LR of vegetables (23 percent of the total) and cereals (14 percent) were the most distributed by genebanks, followed by roots and tubers (12.5 percent), pulses (10 percent) and fruit plants (4 percent). The number of samples of FV/LR distributed to farmers by genebanks, categorized by crop group and geographic region, is provided in Table 2.8. Overall, the largest numbers of FV/LR samples were distributed by national and local genebanks in Latin America and the Caribbean (over 36 000) and Europe (over 11 100).

[13] Albania, Armenia, Azerbaijan, Bangladesh, Eritrea, Ethiopia, Guyana, Indonesia, Nepal, Tunisia.

[14] The countries reported on the same areas for both 2012–2014 and 2014–2019 making it possible to compare the two time periods.

TABLE 2.7

Farmers' varieties/landraces cultivation as a proportion of crop area for selected crops/crop groups and areas in ten selected countries for the 2012–2014 and 2014–2019 reporting periods

Crop/crop group	Area, country	2012–2014		2014–2019		Difference (%)
		Total area (ha)	Area under FV/LR (%)	Total area (ha)	Area under FV/LR (%)	
Apples	(unspecified), Armenia	11 098	4	11 152	3	**–1**
	Eastern and Southern Greater Caucasus, Azerbaijan	25 000	20	24 000	25	**5**
Apricots	(unspecified), Armenia	10 404	97	10 404	97	**0**
	Babek, Shahbuz, Julfa and Ordubad regions of Nakhchivan AR, Azerbaijan	2 200	90	2 100	90	**0**
Barley	Plain and lower mountain areas, Azerbaijan	320 000	10	325 000	4	**–6**
Cassava	Kumaka-Santa Rosa Farming Community, Moruca, Region # 1, Guyana	500	100	320	100	**0**
Cereals	Menzel Habib (Essagui), Tunisia	3 500	75	3 500	75	**0**
Cherries	(unspecified), Armenia	1 531	6	1 531	5	**–1**
Citrus	Lankaran Astara region, Azerbaijan	3 500	25	3 900	20	**–5**
Figs	Absheron, Azerbaijan	3 500	80	3 400	85	**5**
Grapevine	(unspecified), Armenia	17 465	17	16 099	25	**8**
	Plain and lower mountain areas, Azerbaijan	15 000	30	17 000	25	**–5**
Hazelnuts	(unspecified), Armenia	157	97	157	96.8	**0**
Maize	Fier, Shkodra, Dibra, Albania	31 790	18	21 882	26	**8**
	Southern Greater Caucasus, Azerbaijan	30 000	3	32 000	1	**–2**
	Debub, Eritrea	14 081	99	11 191	90	**–9**
	Southern and Western low to mid altitude areas, Ethiopia	1 994 814	51	2 274 102	43	**–8**
Melon	Aran regions, Azerbaijan	8 000	60	7 700	50	**–10**
Oil Plants	Kailali, Nepal	20 000	92	20 500	87	**–5**
Olives	Absheron, Azerbaijan	1 526	4	1 756	2	**–2**
Peach	Nakhchivan AR, Azerbaijan	2 200	75	2 600	50	**–25**
Pearl millet	Anseba, Eritrea	26 222	85	24 856	90	**5**
	Sindhupalchok, Nepal	19 200	86	24 600	74	**–12**
Pears	(unspecified), Armenia	2 928	48	2 957	47	**–1**
	Eastern and Southern Greater Caucasus, Azerbaijan	5 400	70	5 200	65	**–5**
Pomegranate	Aran regions, Azerbaijan	16 000	92	19 000	85	**–7**

(Cont.)

Crop/crop group	Area, country	2012–2014		2014–2019		Difference (%)
		Total area (ha)	Area under FV/LR (%)	Total area (ha)	Area under FV/LR (%)	
Potatoes	Ganja-Gazakh zone, Azerbaijan	25 000	25	28 000	30	**5**
	Gusar, Azerbaijan	3 200	15	3 500	20	**5**
Pulses	Dang, Nepal	27 000	85	27 380	78	–7
	Plain and lower mountain areas, Azerbaijan	12 200	15	10 200	11	**–4**
Rice	Aceh Tengah, Aceh Timur and Pidie Jaya, Simeulue, Indonesia	6 000	12	5 880	11	**–1**
	Hilly, coastal and haor (a wetland ecosystem) areas, Bangladesh	11 372 071	20	11 670 000	12	**–8**
Rye	Aran regions, Azerbaijan	100	8	110	2.7	**–5**
Sorghum	Gash Barka, Eritrea	156 525	80	137 445	90	**10**
	Northern and Eastern low to mid altitude areas, Ethiopia	1 677 486	99	1 828 182	99	**0**
Sour cherries	(unspecified), Armenia	844	98	844	96	**–2**
Stone fruits	Sheki-Zaqatala, Azerbaijan	27 000	70	27 500	75	**5**
Sugar beet	Aran regions, Azerbaijan	5 700	4	6 200	2	**–2**
Tea	Lankaran Astara, Azerbaijan	1 000	70	1 600	55	**–15**
Tef	North-Western and Central Highlands, Ethiopia	3 016 522	97	3 101 178	93	**-4**
Vegetables	(unspecified), Azerbaijan	10 000	50	11 000	55	**5**
	Khotang, Nepal	9 980	48	14 170	74	**26**
Watermelons	(unspecified), Armenia	10 000	5	10 500	3	**–2**
Wheat	Central, South-Eastern and North-Western Highlands, Ethiopia	1 605 654	92	1 789 373	83	**–9**
	Plain and lower mountain areas, Azerbaijan	450 000	2	470 000	1	**–1**
Total		21 045 498	46.4	22 044 069	40.5	**–5.9**

Note: FV/LV = farmers' varieties/landraces.

2.4.4 Summary assessments

Countries reported a relatively large number of programmes, projects and activities addressing the on-farm management of FV/LR, with characterization and evaluation activities most frequently reported. This reflects countries' interests in assessing and documenting FV/LR so as then to be able to deploy them in the most suitable environments and markets, although, as noted above, an analysis of ten countries showed an overall decrease in the cultivation of FV/LR over the reporting period.

FV/LR of cereals were reported to be the most widely cultivated, accounting for 44 percent of the total area under this crop group for the sites reported by countries. Vegetables and cereals were the crop groups most commonly distributed to farmers by national and local genebanks.

Surveys of FV/LR found that a global average of 6 percent of their diversity was threatened, although results from nine out of 18 subregions were more alarming, with the proportions threatened equal to or higher than 18 percent.

TABLE 2.8
Number of samples of farmers' varieties/landraces distributed to farmers by national and local genebanks, by crop group and region

Crop Group	Northern Africa	Sub-Saharan Africa	Latin America and the Caribbean	Oceania	Asia	Europe	Total
Vegetables	16	123	5 362	0	3 074	5 117	13 692
Cereals	0	1 539	3 503	0	1 464	1 626	8 132
Roots and tubers	0	144	6 888	0	13	246	7 291
Pulses	0	1 081	1 764	0	1 628	1 353	5 826
Fruit plants	49	0	437	0	285	1 828	2 599
Pseudo-cereals	0	26	38	0	610	2	676
Herbs and spices	0	3	25	44	225	86	383
Oil plants	2	28	23	0	261	14	328
Forages	0	1	26	11	147	86	271
Ornamentals	0	0	50	0	14	190	254
Nuts	0	1	0	0	10	160	171
Material	0	0	22	0	42	69	133
Sugar crops	1	0	10	0	63	29	103
Stimulants	0	10	88	0	0	0	98
Medicinal plants	0	0	34	0	49	0	83
Fibre plants	0	0	4	0	2	0	6
Multiple*	89	100	17 793	0	0	296	18 278
Total	**257**	**3 056**	**36 067**	**55**	**7 887**	**11 102**	**58 324**

Note: *Brazil reported the distribution of 10 660 samples of farmers' varieties/landraces (FV/LR) of maize, beans and sorghum; 3 375 samples of FV/LR of maize and beans; 3 200 samples of FV/LR of maize, beans, sunflower, groundnut, sesame and *Linum*; and 500 samples of FV/LR of maize, beans, arrowroot and yam. Data provided by 70 countries.

Countries highlighted the challenges they face in undertaking systematic on-farm surveying given the resource-intensive nature of this activity.

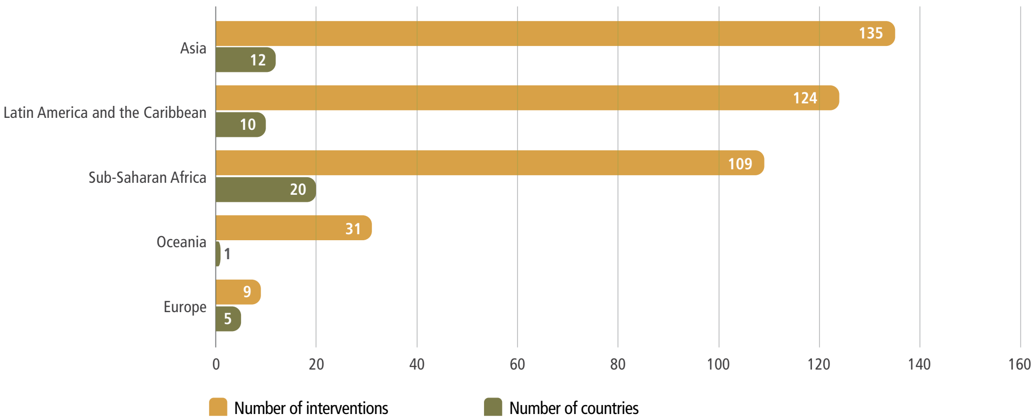
2.5 Restoration of crop systems after disasters

According to EM-DAT, The International Disaster Database (CRED, 2023), more than 4 000 disasters linked to droughts, floods, earthquakes, volcanoes, frost, hail, snow, civil wars, instability, crisis, storms, pests or diseases were reported around the world during the reporting period (2012–2019), affecting nearly 1.3 billion people. The agricultural sector – crop and livestock production, forestry, fisheries and aquaculture – absorbed 26 percent of the overall damages and losses caused by medium- to large-scale disaster events. This implies significant impacts on the livelihoods and on the nutritional status of affected populations (FAO, 2021). These impacts tend to be estimated in terms of monetary and nutritional costs, and not in terms of the loss of cultivated diversity.

Countries reported on assistance provided to farmers to restore crop systems in disaster situations since the publication of the SoW2. Forty-eight reported a total of 408 interventions that focused on the supply of seeds and planting materials for restoring cropping systems after

FIGURE 2.11

Number of reported interventions to restore cropping systems after disasters, and number of reporting countries, by region, 2010–2019



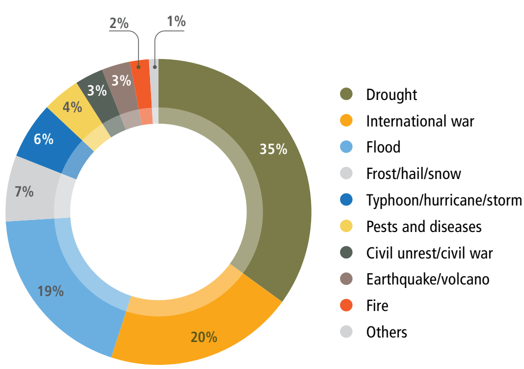
disasters. Sub-Saharan Africa was the region with the largest number of countries reporting interventions following disasters (20 countries – 109 interventions), while the highest number of interventions was reported from Asia (135 interventions – 12 countries). In Latin America and the Caribbean, a total of 124 interventions were reported by ten countries. In Europe, a total of nine interventions were reported by five countries. In Oceania, one country (Papua New Guinea) reported 33 interventions (Figure 2.11).

Climatic events were the cause of about two-thirds of all the interventions, with drought as the most common cause (35 percent), followed by floods (19 percent), frost/hail/snow (7 percent) and typhoon/hurricane/storm (6 percent) (Figure 2.12). International war, civil unrest and war accounted for 23 percent of all interventions at the global level.

Combinations of different interventions are often used to help farmers restore their cropping systems. In 50 percent of the interventions reported by countries, seeds and planting materials were distributed directly to farmers, in 13 percent they were distributed to community seed multiplication sites and in 26 percent to both. One of the major difficulties encountered when distributing seeds and other planting materials after a disaster is the lack of available quality seeds and planting materials from adapted varieties. Such materials must be free of pests and diseases, respond to farmers' needs and be available in sufficient quantities (FAO, 2016). Box 2.5 describes some of the diverse disaster situations that have occurred in different regions of Brazil and the initiatives through which germplasm was distributed to local

FIGURE 2.12

Types of disasters leading to interventions to restore cropping systems, 2010–2019



Notes: Based on 48 country reports.

communities following them.

Sources of the germplasm distributed to farmers for the restoration of cropping systems were reported by 43 countries for 344 interventions (Figure 2.13). Farmers and community seedbanks played a major role, as together they were

Box 2.5
Restoration of farming systems post-disaster in Brazil

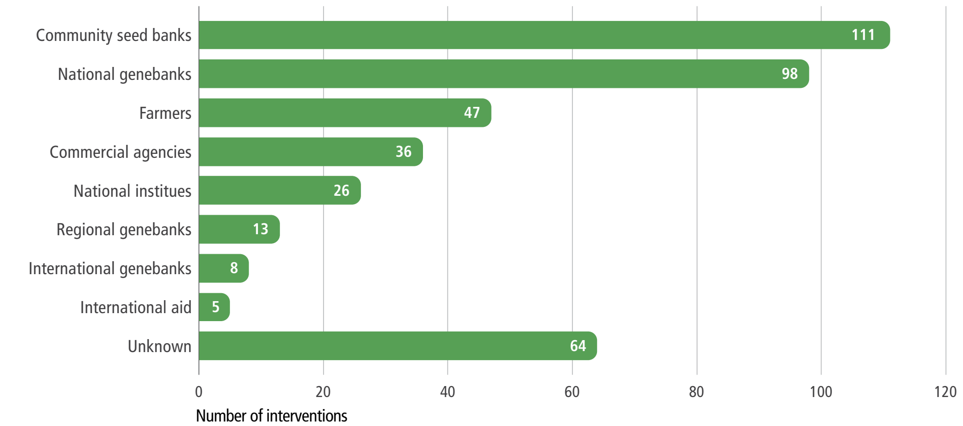
Assistance was provided to farmers in the following disaster situations in Brazil during the reporting period (2012 to 2019). Drought was reported in the southeast, northeast, midwest and south regions, mainly affecting the cultivation of maize, beans, cassava and vegetables. Fires were reported in the northeast and midwest regions, with the cultivation of native fruits, maize, yams, sweet potatoes, arrowroot and fava severely affected. Land conflicts occurred in the southeast, northeast and midwest regions, affecting cassava, broad beans, maize and common beans. At least 14 000 farming families benefited from these interventions and 47 different stakeholders were involved in providing assistance. In general, it was found that annual crops were the worst affected, with maize, common beans, broad bean and cucurbits identified as the crops most frequently reintroduced.

The drought that occurred in the Brazilian semi-arid region (part of the northeast and southeast regions) from 2012 to 2017 was the longest on record according to Brazil's National Meteorological Institute (INMET). During this period of six consecutive years, rainfall was below average, leading to prolonged drought in the region. Initiatives, such as community seed banks and the Food Acquisition Program, helped to minimize the loss of crops by providing seed assistance to 20 240 families.

The largest numbers of samples of farmers' varieties/landraces from the four most affected crop groups were distributed by a number of Brazilian stakeholders, including the Brazilian Agricultural Research Corporation (Embrapa). They included more than 5 000 samples of vegetables, 2 200 of cereals (27 percent of all cereals distributed), 4 705 of roots and tubers (65 percent) and 1 355 of pulses (23 percent).

Source: Data provided by Brazil.

FIGURE 2.13
Sources of germplasm/seeds distributed to farmers after disasters



Notes: "International aid" refers to neighbouring states, FAO and non-governmental organizations. "National/state institutions" refers to research, educational and agricultural national institutions, and departments of agriculture. "Farmers" refers to farmers and seed producers' associations. Based on 48 country reports.

the sources for 39 percent (158) of reported distributions of seeds and planting materials to affected areas. National genebanks and other national institutions accounted for 30 percent of cases (147), commercial agencies for 9 percent (36) and international sourcing for 3 percent (13).

Restoration of agricultural production systems rather than crop diversity was the primary focus of most of the interventions reported. Given the urgency of providing quality seeds and planting materials to farmers affected by disaster situations, the germplasm distributed may not always be fully adapted to local conditions or to the cultural environment, a point noted in the reports from Cameroon and Mali. In some cases, only a few crop species and varieties per crop were selected for distribution. An approach of this kind may result in the dominance of the distributed germplasm over other varieties, and ultimately to the loss of FV/LR, a point noted in the reports from the Philippines and Togo. In most circumstances, however, emergency seed assistance provides no more than a small proportion of the seed sown by all farmers, and so significant impacts on diversity are not to be expected.

Box 2.6 describes a disaster-relief project implemented in Malawi, Mozambique and Zimbabwe in response to Cyclones Idai and Kenneth that provides an example of collaboration between farmers, genebanks, governments and an international organization to support local seed systems.

Box 2.6

Seed-system support to Malawi, Mozambique and Zimbabwe in response to Cyclones Idai and Kenneth

When Cyclones Idai and Kenneth made landfall in Southern Africa in March and April 2019 respectively, the consequences were devastating for farmers, many of whom lost local seed reserves and crops ready for harvest. The cyclones and related floods affected more than 3.8 million people in Southern Africa and destroyed nearly 800 000 ha of standing crops in Malawi, Mozambique and Zimbabwe.

Rebuilding local seed systems is crucial for food and nutrition security but is often not implicit in national emergency response and preparedness plans, which focus on the immediate distribution of quality seed and planting material from adapted varieties. To address this gap, the International Treaty on Plant Genetic Resources for Food and Agriculture (International Treaty) and FAO partnered with the national genebanks of Malawi, Mozambique and Zimbabwe on a three-year project with support from the governments of Germany and Norway. The project – Foundations for rebuilding seed systems post Cyclone Idai: Malawi, Mozambique and Zimbabwe – aimed to improve food and nutrition security, and livelihoods in the longer term.

Through the project, national genebanks and farmers collaborated to rescue, regenerate and return seed to affected communities in Malawi, Mozambique and Zimbabwe, and to strengthen national and regional planning for the protection of local seed systems. The national genebanks of the three countries integrated emergency response measures for plant genetic resources for food and agriculture into national strategies so that governments and communities would be better prepared for future emergencies.

Among the main achievements of the project were the inclusion of seed-system protection and restoration in national and regional strategies, the rescue of crop varieties that were at risk of being lost, and the multiplication and distribution of varieties that respond to farmers' needs and preferences, and to current and future climate conditions. At the same time, the project strengthened the capacities of multiple stakeholders in Malawi, Mozambique and Zimbabwe to benefit from and contribute to the mechanisms of the International Treaty.

Sources: International Treaty on Plant Genetic Resources for Food and Agriculture. 2024. *Safeguarding crop diversity in emergencies*. [Cited 18 October 2024]. https://www.fao.org/plant-treaty/emergencies/seed-systems-in-emergencies/en; and International Treaty on Plant Genetic Resources for Food and Agriculture. 2024. *Germany supports Treaty in rebuilding seed systems in Southern Africa after Cyclone Idai*. [Cited 3 September 2020]. https://www.fao.org/plant-treaty/news/news-detail/en/c/1305962/

2.5.1 Summary assessment

Over 4 000 disasters, affecting 1.3 billion people, were recorded worldwide in the 2012–2019 period. Countries reported that more than two-thirds of the interventions undertaken to restore cropping systems were implemented in response to climactic events, with drought being the most prominent, followed by floods. Reported efforts to restore cropping systems following disasters most commonly involved the distribution of seeds and planting materials directly to farmers, mainly by community seed banks and national genebanks.

The restoration of agricultural productivity, as opposed to the restoration of crop diversity, was the primary focus of most of the interventions reported, with only a few crop species and varieties per crop selected for distribution. Countries stressed that pre- and post-disaster assessments of crop diversity are needed to allow the targeted restoration of cropping systems.

2.6 Community engagement in the conservation and management of wild and cultivated plant genetic resources for food and agriculture

2.6.1 Participatory crop improvement

Participatory crop improvement is a well-established framework for breeding local crops. Several diverse approaches to participatory crop improvement have been documented, including PPB and PVS (Sperling *et al*., 2001; De Haan *et al*., 2019; Ceccarelli and Grando, 2020). The reports from countries highlight the use of PPB and PVS activities predominantly in crossing, selection and field evaluation of FV/LR. Latin America, followed by Africa,[15] were the regions with the largest number countries reporting the implementation of PPB or PVS. Two Asian countries (Jordan and Nepal) mentioned the use of PVS. France is the only country in Europe that reported PPB or PVS activities. However, a review paper on PPB in European countries (including France, Germany, Italy and Spain) identified 26 projects covering 14 crops, 13 of which started after 2011 (Colley *et al*., 2021). A more dynamic and decentralized form of PPB was piloted in six countries (Bhutan, Ethiopia, the Islamic Republic of Iran, Jordan, Nepal and Uganda) to improve farmers' use of crop varieties in rainfed farming systems (IFAD, n.d.).

[15] Chile, Costa Rica, Cuba, Guatemala, Mexico, Nicaragua, and Trinidad and Tobago in Latin America and the Caribbean; Ethiopia, Nigeria, South Africa, Zambia and Zimbabwe in Africa.

2.6.2 Registration of farmers' varieties

Registration of FV/LR can contribute to their conservation. The Plurinational State of Bolivia, the Lao People's Democratic Republic, Nepal and Zimbabwe are among countries that have been piloting this approach. In the Philippines, the development of an alternative registration system resulted in the registration and release of FV/LR improved through PVS (De Jonge *et al*., 2021). The formation of seed clubs in Viet Nam allowed breeders to work with farmers to promote varietal selection through PPB and enabled the national registration of local varieties; this has improved farmers' access to quality seeds and planting materials from preferred varieties (Furman *et al*., 2021; FAO, 2022) (Box 2.7). Registration of FV/LR provides legal pathways towards their commercialization, and this can help generate income and other benefits for smallholder farmers in addition to facilitating the conservation of the varieties through use.

2.6.3 Globally Important Agricultural Heritage System

Traditional agriculture systems are still providing food for some 2 billion people. They also sustain biodiversity, livelihoods, practical knowledge and culture. The Globally Important Agricultural Heritage System (GIAHS) approach was developed by FAO as a means of identifying and safeguarding such systems (including the

Box 2.7
Seed clubs in Viet Nam provide a link between formal and informal seed sectors

In Viet Nam, the Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) and the Mekong Delta Development Research Institute of Can Tho University (MDI-CTU) have been collaborating with communities on the formation of seed clubs to promote local seed-supply systems through seed conservation and exchange and crop improvement activities. SEARICE and MDI-CTU facilitate activities in: (i) participatory variety rehabilitation to restore the original characteristics of the farmers' variety/landrace through selection; (ii) participatory plant breeding, which involves the participation of farmers in decision making throughout the process of varietal development; and (iii) participatory variety selection, where farmers grow and select varieties in their own fields, enabling breeders to learn which varieties are preferred by farmers and perform well on farm.

These activities bridge the formal and informal seed systems (Tin et al., 2011) and have resulted in the development of 360 farmers' varieties, five of which are nationally certified. The formal registration of farmers' varieties is made possible through funding provided by SEARICE and by the policy and technical assistance provided by MDI-CTU. This approach empowers communities and is fundamentally important to efforts to improve access to quality seeds, maintain local crop diversity, and enhance linkages between the formal and informal seed sectors.

Source: Tin, H.Q., Cuc .H, Be, T.T., Ignacio, N. & Berg, T. 2011. Impacts of seed clubs in ensuring local seed systems in the Mekong Delta, Vietnam. *Journal of Sustainable Agriculture*, 35(8): 840–854. https://doi.org/10.1080/10440046.2011.611746

agricultural biodiversity, knowledge systems and culture they encompass) and their associated landscapes. The approach entails the recognition of global agricultural heritage, including its socioeconomic and cultural features, while promoting resilience and sustainability. Between 2005 and 2020, FAO designated 62 systems in 24 countries as agricultural heritage sites. The establishment of these sites contributes to the conservation and sustainable use of local, well-adapted germplasm as well as to promoting the development of agricultural value chains (see Box 2.8).

2.6.4 Community seed banks

CSBs are a means of saving and sharing seeds among farmers and gardeners; therefore, they have a role in supporting crop diversity. CSBs can be defined as local, informal or formal institutions whose core function is to collectively maintain seeds for local use (Development Fund, 2011; Vernooy *et al*., 2017; Andersen *et al*., 2018). Reflecting an increased interest in this approach to the conservation and sustainable use of FV/LR, 21 countries across the various regions of the world report the establishment of CSBs during this reporting period (more than 600 CSBs). Countries indicate that the key role played by the CSBs was the distribution of FV/LR of local crops to farmers.

CSBs, seed fairs and diversity fairs all serve to promote the exchange of seeds and associated knowledge (a point noted in the reports from Brazil, Lebanon, Mali, Mexico, Nepal, Nicaragua, South Africa, Uganda and Zambia). In Mali and South Africa, the most active participants in CSB management are reported to be women, while in Lebanon, both men and women of various ages are reported to be involved in the management of CSBs. The report from Nicaragua mentions that women are recognized as providing more efficient management of CSBs.

In Europe, more than 100 CSBs were identified as active as of 2017 (Diversifood, 2018). In Canada, events called "Seedy Saturdays"[16] are organized to encourage the use of open-pollinated and heritage seeds, enable local seed exchange,

[16] Further information at https://seeds.ca/seedy-saturday

Box 2.8
Nishi Awa Steep Slope Land Agriculture System, Japan

Along the steep mountains of Nishi Awa, Japan, family farmers continue to cultivate crops using traditional methods. The grasslands that are essential for maintaining the system's sloping fields are home to various rare plants and animals. Locally adapted, resilient crops have traditionally been cultivated, including local varieties of buckwheat, foxtail millet, barnyard millet, proso millet, tea, fruit trees and vegetables. These represent a valuable source of food for local communities but have gradually been abandoned in favour of rice cultivation. Only a few farmers have continued to cultivate local varieties of millets and buckwheat, and it is thanks to them that these varieties have been maintained.

The Globally Important Agricultural Heritage Systems (GIAHS) designation of this area (GIAHS, 2024) has led to the conservation, multiplication and distribution of local germplasm being actively fostered at the community level. Produce is both consumed locally and shipped to the Japan Agricultural Cooperatives and farmers' markets, providing a valuable source of income. The GIAHS designation has also promoted a new form of tourism, with activities such as hands-on farming experiences being offered to visitors.

Source: GIAHS (Globally Important Agricultural Heritage Systems). 2024. Nishi-Awa Steep Slope Land Agriculture System, Japan. In: *FAO*. [Cited 16 November 2024]. https://www.fao.org/giahs/giahsaroundtheworld/designated-sites/asia-and-the-pacific/nishi-awa-steep-slope-land-agriculture-system/en

and educate the public about seed saving and environmentally responsible gardening practices (Seeds of Diversity, 2024). In the United States, organizations such as Seed Savers Exchange,[17] a non-profit dedicated to preserving and sharing heirloom seeds, assists gardeners from around the country to offer seeds from the crops they have grown. These types of exchanges have saved thousands of rare heirloom varieties from extinction by connecting seed stewards and enabling them to pass on seed-saving traditions to the next generation (Seed Savers Exchange, 2024).

While CSBs were initially established and promoted within the framework of donor-funded projects, national public-sector institutions are now establishing and promoting them in some countries. For example, the 2018 National Seed Policy in Uganda specifically refers to CSBs as part of a strategy to "strengthen research and development for the seed sector" (Government of Uganda, 2018).

In 2018, FAO, in collaboration with Bioversity International, conducted a survey of CSBs with the aim of characterizing their functions, composition and foci. Responses were received from 82 CSB representatives in 37 countries. Eighty-two CSBs had legal status (were registered as an association or cooperative), and all but two operated as non-profit organizations. The majority of the CSBs were involved in short-term storage of FV/LR and their multiplication and distribution to farmers. Other activities reported were education and training, awareness raising, PPB and seed production. Membership ranged from fewer than ten to more than 14 500, with the number of women members varying from zero to 5 000. While some CSBs distributed large amounts of seed (to between 1 000 and 10 000 recipients), over half distributed to fewer than 100 recipients. The surveyed CSBs identified a range of constraints to the effective implementation of their activities, including shortages of financial and human resources, storage capacity, equipment, land availability, seeds and varieties, as well as a lack of supportive seed laws and policies, and market incentives. Forty-four CSBs were found to be part of larger networks that facilitate the sharing of resources, experiences and technical knowledge. All respondents indicated that they could both benefit from being part of a larger knowledge-sharing platform and contribute to such an initiative.

[17] Further information at https://exchange.seedsavers.org/home

2.6.5 Indigenous Peoples and local communities in *in situ* conservation and on-farm management of plant genetic resources for food and agriculture

The Kunming-Montreal Global Biodiversity Framework sets out 23 global targets for living in harmony with nature and mitigating biodiversity loss. The contributions and rights of Indigenous Peoples and local communities are reflected in several of these targets (CBD, 2022).

A number of reporting countries (including Bangladesh, Cameroon, Canada, Costa Rica, Cuba, Guyana, Namibia, Nicaragua and South Africa) highlight the roles of Indigenous Peoples and local communities in *in situ* conservation of CWR and WFP. While most countries provide limited information on this, Canada provides a detailed review of the development of research and national policies on Indigenous Peoples' knowledge. It reports that its Indigenous Agriculture and Food Systems Initiative (2018–2022/23) includes programmes and projects such as Indigenous Pathfinder, which supports the participation of Indigenous Peoples in the agrifood sector, and the Indigenous Support and Awareness Office, which disseminates information material for Indigenous Peoples, including on PGRFA and associated traditional knowledge.

Countries highlight the importance of integrating traditional knowledge into legal frameworks. In some countries, traditional knowledge is reflected in national plans and legislation developed in the context of the implementation of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (Nagoya Protocol).[18] Among African countries, for example, Namibia reports that it has incorporated traditional knowledge into its national plans in line with the Nagoya Protocol. South Africa mentions that its National Strategy for Plant Conservation (implemented in 2015) is well aligned to the Global Strategy for Plant Conservation and has a specific focus on CWR and associated traditional knowledge. Zambia reports that its Protection of Traditional Knowledge, Genetic Resources and Expressions of Folklore Act of 2016 provides a means of protecting WFP and other PGRFA. Among Latin American countries, Costa Rica reports some progress in advancing the application of its Law 7788 on biodiversity with regard to the protection of traditional knowledge, including by reinforcing the need for prior informed consent in accessing genetic resources and traditional knowledge, through the ratification of the Nagoya Protocol in 2014. Among countries from Asia, Bangladesh reports that it adopted the Bangladesh Biodiversity Act, 2017, which builds upon and extends the principles outlined in the Biodiversity and Community Knowledge Protection Act and reflects the country's concern about preserving traditional knowledge on PGRFA, including FV/LR.

Countries reported 550 different species of plants used in the traditional diets of Indigenous Peoples and local communities, including 75 species used for food, 52 used for beverages and 400 with medicinal uses. For example, Nicaragua reports that 293 wild and domestic species are used by its various Indigenous Peoples and local communities. The use of CWR and WFP is also reported by Guyana, where several key species found in 14 different agroecological zones are used for food, feed and nutraceuticals by local communities.

The need to improve the documentation of ethnobotanical information as part of the evaluation and characterization of germplasm and to protect local seeds and varieties is reported by countries from sub-Saharan Africa (Benin, Cameroon and Ghana), Northern America (Canada), Latin America and the Caribbean (Brazil, Costa Rica, Mexico and Uruguay) and Asia (Lebanon, Jordan, Mongolia, Nepal and the Philippines). Countries from sub-Saharan Africa (Namibia, South Africa, Uganda and the United Republic of Tanzania), Asia (Nepal) and Latin America and the Caribbean (Cuba) report that

[18] See https://www.cbd.int/abs/about/default.shtml

in situ conservation projects have contributed to the recognition and maintenance of traditional knowledge associated with FV/LR.

A number of countries report that projects undertaken in the past few years have focused on the inclusion of women in on-farm activities. For example, Albania and Estonia (Europe), Brazil, Cuba, Guatemala, Mexico, Peru and Uruguay (Latin America and the Caribbean), Nigeria, the United Republic of Tanzania and Zambia (sub-Saharan Africa) and Nepal (Asia) emphasize the need for gender equity and/or for the involvement of women and youth in on-farm conservation projects and programmes. A number of countries have sought to address such concerns by developing regulatory frameworks that support traditional knowledge and gender inclusion. For example, the Seeds and Plant Varieties (Amendment) Act of Kenya (2016), the National Agriculture Policy of Malawi (2016) and the Access to Biological and Genetic Resources and Associated Traditional Knowledge Act of Namibia (2017) encourage women's participation in the conservation of PGRFA and related traditional knowledge.

2.6.6 Summary assessment

The successful conservation and management of PGRFA requires the support of a diverse range of stakeholders, including local communities. Countries highlight the importance of participatory crop improvement, including PPB and PVS. They also stress that registering farmers' varieties and building linkages with plant breeders provide legal pathways towards the commercialization of the varieties, thus generating income while facilitating conservation of PGRFA diversity through use. An example of an initiative that promotes the use of local crop diversity is FAO's GIAHS, which generates income for local communities, including through developing local value chains and promoting agrotourism. Between 2005 and 2020, FAO provided support for designating 62 systems in 24 countries as agricultural heritage sites.

Countries report that CSBs were an important resource for smallholder farmers in conserving and distributing FV/LR. Over the reporting period, 21 countries, across different regions, reported the establishment of CSBs, with the total number reported amounting to more than 600.

Improving the documentation of ethnobotanical information was highlighted as a major need by countries across different regions.

2.7 Threats and challenges to *in situ* conservation and on-farm management of plant genetic resources for food and agriculture

Recent global assessments unanimously agree that the world is facing an unprecedented biodiversity crisis and that the rate of biodiversity loss will accelerate unless urgent action is taken (RBG Kew, 2016; Antonelli *et al.* 2020; FAO, 2019b; IPBES, 2019a; IPBES 2019b; CBD, 2021). An assessment of the data from the country reports shows that during the reporting period (2012–2019), a total of 2 591 PGRFA taxa (including FV/LR, CWR and WFP) were reported to be threatened (defined as any crop, crop variety, CWR or WFP that is no longer cultivated or no longer occurs *in situ* in most of its previous areas of cultivation or occurrence) (See FAO, 2020), which represents 42 percent of the total number of taxa included in the analysis (6 210).[19]

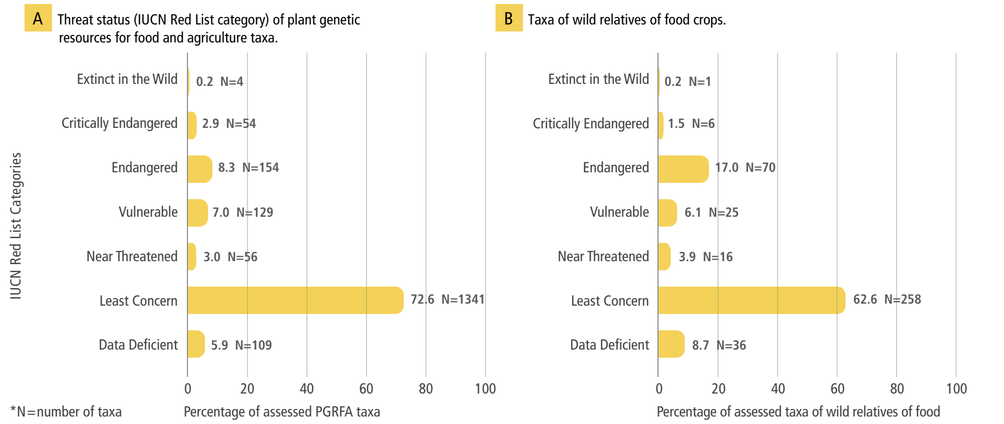
To complement the data from the country reports, an analysis of the threat status of identified PGRFA taxa, including of wild relatives of food crops, was undertaken using the categories and criteria of the IUCN Red List of Threatened Species (IUCN, 2024a, b) and data from the IUCN Species Information Service.[20] Results showed that 1 847 PGRFA taxa (30 percent of all the PGRFA taxa included in the analysis) and 412 taxa of wild relatives of food crops (32 percent of all the CWR taxa included in the analysis) have been assessed

[19] See Section 2.2.1

[20] Further information at https://www.iucnredlist.org/assessment/sis#:~:text=The percent20IUCN percent20Species percent20Information percent20Service,on percent20The percent20IUCN percent20Red percent20List

FIGURE 2.14

Threat status (IUCN Red List category) of plant genetic resources for food and agriculture taxa (A) and taxa of wild relatives of food crops (B)



Source: Based on data from IUCN. 2024. *IUCN Red List Species Information Service*. [Cited 24 October 2024] https://www.iucnredlist.org/ and country reports.

according to the IUCN Red List categories. The majority of the assessed PGRFA and CWR taxa fall into the Least Concern category (Figure 2.14).

The State of the World's Plants and Fungi 2023, published by the Royal Botanic Gardens, Kew, estimated that 45 percent of plants species were threatened with extinction at the time of analysis (Antonelli et al., 2023). The IPBES Global Assessment Reports on Biodiversity and Ecosystem Services (IPBES, 2019a; IPBES, 2019b) state that nature is declining globally at unprecedented rates in human history and that some 1 million species are threatened with extinction, including many CWR species that are important for food and nutrition security and lack protection. It should also be noted that none of the Aichi Biodiversity Targets within the framework of the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020, including Target 13,[21] which covered the conservation of PGRFA, were achieved.

The The State of the World's Biodiversity for Food and Agriculture (FAO, 2019b) reports on the decline of CWR species in specific places affected by climate change and on the status of wild species used for food. IUCN reports that 610 plant species used as human food are considered threatened, of which 101 species are categorized as Critically Endangered, 248 as Endangered and 261 as Vulnerable (IUCN, 2024b). The two largest specific IUCN Red List assessments of CWR taxa in Europe assessed 571 CWR species and found 11 percent were threatened (Kell *et al.*, 2012). In Mesoamerica, 224 CWR species were assessed and 27 percent were found to be threatened (Goettsch *et al.*, 2021). Ulian *et al.* (2020) reported that nearly 30 percent of 7 000 WFP species were listed on the IUCN Red List of Threatened Species as of 2020 and that 11 percent of those (234 species) were classed as Threatened. Although a number of these studies show similar results to the analyses of country data over the reporting period, it is important to note that the studies were carried out in different sets of countries, over different time periods and utilizing different data and analyses. Direct comparisons are therefore not possible.

[21] Aichi Biodiversity Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socioeconomically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity. Further information at https://www.cbd.int/sp/targets/rationale/target-13

In contrast to wild PGRFA, our knowledge of the threat status of FV/LR on-farm is very limited. *The State of the World's Biodiversity for Food and Agriculture*, however, highlighted that most countries reported a decline of FV/LR diversity (FAO, 2019b). A more recent study highlighted that more than 50 percent of documented FV/LRs at 17 study sites across five agroecological zones in India were considered as threatened, suggesting that conservation interventions are required to prevent large-scale genetic erosion on-farm (Dulloo *et al*., 2021).

Countries report a diverse range of threats to cultivated PGRFA (Table 2.9). Most mentioned the negative impact of climate change and of natural and human-induced disasters that increase the incidence and severity of various biotic and abiotic stresses (e.g. the effects of heat, floods, diseases and pests). Box 2.9 describes the impact of climate change on local PGRFA in Eritrea.

Other challenges reported by countries include the replacement of FV/LR with improved varieties, market pressures, and changes in land use caused by modernization and urbanization. Another threat to diversity is that changes in eating habits and diets are reducing demand for FV/LR, a point noted in the report from the Philippines. Some countries mentioned that traditional knowledge may also be threatened. For example, the migration of younger people to urban areas has led to the erosion of knowledge about the on-farm management of local crops.

Overall, the threats to wild and cultivated PGRFA reported by countries were similar to those reported in recent literature (Antonelli *et al*. 2020; Engels and Ebert, 2021; Gatto *et al*., 2021; Khoury *et al*., 2022), which identifies the major causes of genetic erosion of PGRFA diversity as intensive, monocultural agriculture, use of improved varieties, overharvesting in the wild, habitat modification, habitat loss and fragmentation, including deforestation, rapid expansion of residential and commercial developments, pollution, introduction of invasive species, loss of traditional knowledge and traditional food culture, and climate change. The major reported threats to PGRFA *in situ* were also the same as those reported in the SoW2 (climate change, habitat modifications, invasive alien species and replacement of traditional with modern varieties).

Understanding the status of PGRFA *in situ*, including identifying threats and gaps in knowledge, requires adequate tools and monitoring mechanisms. A major challenge is the absence of adequate baselines and tools for long-term monitoring, a point noted in the reports

TABLE 2.9

Threats to wild and cultivated plant genetic resources for food and agriculture reported by countries

Threats to wild and cultivated PGRFA	No. of countries	PGRFA affected
Climate change (severe droughts, cyclones, flooding, frequent bush fires) and natural disasters (seismic activity: earthquakes, volcanic eruptions)	32	Wild and cultivated
Loss of cultivation skills and knowledge	21	Cultivated
Replacement of FV/LR by improved varieties	19	Cultivated
Change in land use because of urbanization (deforestation, infrastructural development)	18	Wild and cultivated
Overexploitation (e.g. overgrazing, overharvesting, increased demand)	10	Wild
Invasive alien species, and pest and disease outbreaks	9	Wild and cultivated
Ecosystem degradation (wetland encroachment, soil depletion and erosion)	4	Wild and cultivated
Lack of specialized equipment for cultivation, sowing and harvesting	2	Cultivated
Large-scale mining	2	Wild and cultivated

Notes: PGRFA = plant genetic resources for food and agriculture. FV/LR = farmers' varieties/landraces.

Box 2.9

Impact of climate change on local plant genetic resources for food and agriculture in Eritrea

In recent years, climate change has been found to seriously affect production in Eritrea. Several pasture plant species growing wild and farmers' varieties of barley, sorghum, maize, finger millet and other crops are classified as endangered. Some varieties of sorghum, maize and finger millet are sown in autumn, and if rainfall is insufficient at this time of year these varieties cannot be sown. In addition, farmers have turned to sowing cash crops such as teff (*Eragrostis* tef) in areas that were previously planted with sorghum. For example, this occurred in the Adi Quala administrative subregion of the agroecological Central Highland Zone. Cultivation areas have also been significantly reduced for local six-row barley varieties, Kuento and Dessie, which require relatively high levels of moisture compared to other barley varieties. Grain legumes have been the worst affected, mostly because of drought, and local broad beans and peas are threatened. The frequency and abundance of several crop wild relatives are being affected. Wild leafy vegetables, which are important sources of food, are endangered as a result of climate change and overgrazing..

Source : Data provided by Eritrea.

from several countries, including Indonesia, the Kingdom of the Netherlands, Papua New Guinea and the Republic of Moldova. The availability of data on the extent and distribution of PGRFA is generally constrained by funding shortages, inadequate methodologies for monitoring temporal changes in the diversity, and a lack of adequate information systems.

For wild plant species, the IUCN Red List of Threatened Species[22] is currently the best tool for assessing species extinction risks to inform conservation policies, planning and priority actions. It is increasingly being used to assess the extinction risks of PGRFA at different geographical scales (Blitz *et al*., 2011; Goettsch *et al*., 2021). The IUCN Red List Index[23] has been developed for use in monitoring progress towards global biodiversity targets but also for monitoring specific groups of species, including plants and CWR (Brummitt *et al*., 2015).

The World Database on Protected Areas[24] and the global database for OECMs managed by the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) are the key tools for assessing the area covered by protected areas and OECMs (see above) (IPBES, 2019a; UNEP-WCMC and IUCN 2020; CBD, 2021; CBD, 2022). The Protected Planet reports (UNEP-WCMC and IUCN, 2016; 2020, 2022) provide regular updates on the coverage of protected areas around the world.

There is currently no globally accepted methodology for assessing the extinction risk and genetic erosion of FV/LR on farm. The monitoring of FV/LR diversity thus remains underdeveloped and knowledge of genetic change remains limited. Dawson *et al*. (2023) proposed a methodology for long-term monitoring of FV/LR in areas of high diversity whereby a network of complementary sites is identified, and semi-standardized methods and metrics are used to obtain baseline data that can be tracked over time. The Platform for Agrobiodiversity Research has developed a tool (the Diversity Assessment Tool for Agrobiodiversity and Resilience)[25] for monitoring crop diversity at the varietal level.

2.8 Gaps and needs

Surveys, inventories and knowledge of the conservation status of plant genetic resources for food and agriculture

A leading constraint to successful, long-term conservation of wild and cultivated PGFRA is

[22] Further information at https://www.iucnredlist.org

[23] Further information at https://www.iucnredlist.org/assessment/red-list-index

[24] Further information at https://www.protectedplanet.net/en

[25] Further information at https://www.datar-par.org

the lack of standardized and consistent baseline data on their status *in situ* and on farm. There is a need to establish and support national, regional and global inventories of CWR, WFP and FV/LR conserved and managed *in situ*. This will require better cooperation with botanic gardens, relevant academic departments and other stakeholders, including local authorities. Comprehensive surveys and inventories of FV/LR in agricultural areas, and of CWR and WFP inside and outside protected areas, to identify populations and their locations are needed. These surveys should also be used to document traditional knowledge associated with FV/LR and WFP. Effective monitoring of these resources will require coordination between nature conservation authorities and genetic resources institutions.

There is currently no globally accepted methodology for assessing the extinction risk and genetic erosion of FV/LR on farm. Improved methodologies for assessing the impact of threats on FV/LR, CWR and WFP genetic diversity are urgently needed. Development and use of appropriate technologies and frameworks for active management and monitoring of wild and cultivated species populations, including generic informatics tools that facilitate the planning and implementation of *ex situ* and *in situ* conservation measures for CWR, WFP and FV/LR, are also needed.

Complementary conservation

Combining *in situ* and *ex situ* strategies is crucial to the sustainable, secure, and cost-effective long-term conservation of wild and cultivated PGRFA. CWR and WFP in the face of increasing threats from climate change, including new biotic and abiotic challenges. Moreover, many FV/LR, which are primarily grown by small-scale farmers in traditional systems, are at risk of disappearing as a result of their continued marginalization and the abandonment of rural areas. Linkages between genebanks, protected area authorities, Indigenous Peoples, farmers/landowners and local communities need to be improved in order to facilitate the implementation of joint diversity assessments, monitoring activities for *in situ* and on-farm diversity and targeted collecting missions to ensure safety back up in genebanks.

Policy support

There is an overall lack of adequate policies and legislation governing the *in situ* conservation and on-farm management of PGRFA in part because of a lack of awareness of the importance of PGRFA, especially among policymakers. There is a need to review policy and regulatory frameworks for *in situ* conservation and on-farm management at the country and regional levels in order to define and streamline the institutional mandates of agencies responsible for biodiversity and PGRFA conservation. Countries should develop clear policy statements on CWR for inclusion in their conservation action plans and other relevant instruments. Surveys/inventories of *in situ*/on-farm PGRFA need to be included in the plans of departments of agriculture to ensure that these activities are adequately resourced and monitored. National policy, legislative and regulatory measures for PGRFA need to be strengthened to ensure their systematic conservation and facilitate their use.

Policy briefs on the value of FV/LR, CWR and WFP need to be developed to raise awareness among policymakers. Information on FV/LR, CWR and WFP needs to be mainstreamed into sectoral policies and development plans. Awareness raising among the managers of protected areas about the presence of CWR, their importance and the need to specifically include them in management plans is also needed. Improving communication and coordination between national focal points for the CBD, the Commission and the International Treaty could help promote the inclusion of CWR, WFP and FV/LR in National Biodiversity Strategies and Action Plans (NBSAPs) and other policies.

Financial support for in situ conservation
Many countries report a lack of sufficient and sustainable funding for *in situ* conservation and on-farm management of PGRFA. Long-term investment can help ensure the sustainability of conservation activities and improve complementarity between *in situ* and *ex situ* conservation. This needs to include increased government allocation of resources to programmes targeting the *in situ* conservation of CWR and WFP through networked protected areas and OECMs, and to the provision of direct benefits, including financial incentives, to farmers for the continued management of FV/LR on farm.

Human capacity
A lack of qualified personnel, including a lack of expertise in plant taxonomy, conservation and population genetics, statistics and informatics, is reported to be a common constraint to the effective *in situ* conservation of PGRFA. These topics are especially relevant to the completion of comprehensive inventories. Unfortunately, many of them are not necessarily of interest to young scientists. Capacity-development opportunities such as certificate programmes or undergraduate study for existing staff are needed to fill gaps in capacity.

There is also a need for awareness raising among farmers, particularly young farmers, for on-farm conservation and management of FV/LR. Farmers need to be involved in data and information generation relevant to the on-farm management and improvement for FV/LRs, including in field testing and evaluation. Promoting linkages between genebanks, breeders, farmers and their CSBs is an important means of fostering knowledge exchange and collaboration. Enhanced collaboration is needed, including through activities such as participatory variety selection and participatory plant breeding, which can facilitate the development and adoption of well-adapted seeds and planting materials.

Networking and information sharing
Limited access to, and sharing of, information are reported by many countries to be constraints to the effective *in situ* conservation and on-farm management of PGRFA. Access to specific information on CWR and WFP, for example on their occurrences in protected areas, OECMs, herbaria, genebanks, CSBs and botanic gardens, must be facilitated via national, regional and global databases. The development and strengthening of networks are important means of promoting linkages between *in situ* conservation and on-farm management and *ex situ* conservation facilities that provide a backup and facilitate use by farmers and breeders. Exchange of knowledge within and among countries on CWR, WFP and FV/LR and best practices in their *in situ* conservation and on-farm management is needed.

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Chapter 3

THE STATE OF *EX SITU* CONSERVATION

Chapter 3

The state of *ex situ* conservation

3.1 Introduction

PGRFA are increasingly threatened by urban encroachment into farmland and forests, unsustainable use of natural resources, environmental changes such as climate change and the emergence of novel pests and diseases, the promotion of genetically uniform varieties, changing patterns of human consumption, and inadequate legislative and policy frameworks. Efforts to conserve PGRFA aim to harness their diversity to improve food security and nutrition. These efforts have a strong focus on *ex situ* conservation, i.e. safeguarding PGRFA outside their natural or cultivated environments. In addition to providing a controlled environment in which diversity can be safeguarded, *ex situ* conservation facilitates targeted access to crop diversity by plant breeders, researchers and other users that need to obtain specific genotypes and traits. It complements *in situ* conservation in the natural or cultivated habitats where the respective PGRFA acquired their specific, and often unique, characteristics. Additionally, *ex situ* collections can be a source of germplasm for restoration purposes.

The conservation methods used in genebanks depend on the biological nature of the accession in question and can include storage of orthodox seeds[1] at low temperatures, maintenance of living plants in fields or greenhouses, storage of plant materials under slow-growth conditions *in vitro* or storage of cryopreserved plant materials. These methods all involve the following elements: identification of accessions; maintaining viability; maintaining genetic integrity during storage and regeneration; maintaining germplasm health; ensuring the physical security of collections; promoting the availability, distribution and use of germplasm; ensuring the availability of information; and proactive management (FAO, 2014). These practices require the development of risk-management plans, standard operating procedures and quality-management systems (CGIAR Genebank Platform, 2021a). FAO has developed international standards and guidelines (FAO, 2014; FAO, 2022a,b,c) to support *ex situ* conservation.

The importance of *ex situ* conservation of PGRFA is reflected in its mention in Target 2.5 of the SDGs: "By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed" (FAO, 2023a). Countries' annual reporting commitments under this target includes providing data for Indicator 2.5.1.a: "Number of plant genetic resources for food and agriculture secured in medium- or long-term conservation facilities."

This chapter addresses *ex situ* conservation efforts worldwide. The focus is predominantly on genebanks but the role of botanic gardens is also discussed, as many of them conserve PGRFA, including CWR and WFP.

1 Seeds that can be dried to lower moisture content and stored at low temperatures without damage to increase seed longevity.

The assessment of the status of *ex situ* conservation is based mainly on data provided by countries to FAO through the WIEWS Reporting Tool (FAO, 2024a) as part of their reporting on progress in the implementation of the GPA2 and on SDG Indicator 2.5.1.a (FAO, 2024b). It also draws on data provided by regional and international research centres, on country narrative reports (FAO, 2019a) and where applicable on the wider literature. Where feasible, comparisons with the previous *State of the World* reports are highlighted. A brief summary is provided at the end of each section.

Data on *ex situ* collections discussed in this chapter are based on those reported for SDG Indicator 2.5.1.a to FAO in 2023 and include national, regional and international genebank holdings as of the end of 2022, unless otherwise specified. These holdings comprise base collections and active collections that will eventually become part of base collections, all conserved under medium- or long-term storage conditions.

3.2 Overview of *ex situ* collections

Germplasm holdings of over 5.9 million accessions are conserved under medium- and long-term storage conditions in the collections of 852 national genebanks in 116 countries, four regional genebanks and 13 international genebanks (Figure 3.1). They represent about 7 300 genera and 51 500 species from 394 botanical families. National genebanks hold 84 percent of all germplasm conserved, the international centres 15 percent and the regional centres 1 percent. Compared to the 2009 figures presented in the SoW2 (FAO, 2010), the overall growth in germplasm holdings is estimated at 9 percent: specifically, 6 percent in national genebanks, 11 percent in regional genebanks and 19 percent in international genebanks. The biological status of the germplasm conserved is documented for 72 percent of the accessions reported. About 1 532 000 are FV/LR and 727 000 are wild materials, of which approximately 548 000 are CWR and 47 000 are WFP. The remaining accessions are improved varieties and breeding materials. The country of origin is known for approximately 70 percent of all the accessions, 88 percent of the wild materials and 91 percent of the FV/LR. Food crops, including cereals, pulses, vegetables, fruit plants, oil plants, roots and tubers, herbs and spices, pseudo-cereals, sugar crops and nuts, account for 73 percent of all the germplasm conserved. The vast majority (79 percent) of accessions are conserved as seed, followed by conservation in field collections and *in vitro*.

The international community has made great strides in taking advantage of the Svalbard Global Seed Vault (SGSV) as a long-term black-box storage facility, especially benefiting from the increased coordination and financial support for packaging and shipment provided by the Crop Trust and the Government of Norway. At the end of 2022, approximately 41 percent of all *ex situ* holdings were safety duplicated, a significant increase from the 15 percent safety duplicated in 2014. Over 1 million accessions, or 43 percent of the safety-duplicated holdings and 23 percent of all accessions stored as seed, were deposited at SGSV,[2] as compared to fewer than half a million in 2014. This increase demonstrates that countries are increasingly taking advantage of SGSV as a long-term black-box storage facility. Although field collections are especially vulnerable to germplasm losses caused by pests, diseases or natural disasters, the level of safety duplication of germplasm conserved in field genebanks is low overall (13 percent). The establishment of a sustainable, long-term cryo-storage backup for species that are vegetatively propagated or produce recalcitrant seeds could prove as successful for these species as SGSV has been for species with orthodox seeds (Acker *et al.*, 2017). While this would require substantial initial expenditure on infrastructure and research into the methodologies needed at the species level, the long-term running costs would be lower than

[2] Further information at https://www.seedvault.no

those for maintaining field or *in vitro* collections.

Degree of uniqueness is estimated to be around 37 percent of total holdings. Continued rationalization efforts driven by molecular techniques and improved information management have resulted in some progress being made at the country level and by international genebanks with regard to unwanted duplications. However, redundancy within and among collections remains poorly documented overall and requires continued attention. One cause of concern is that a number of species are conserved in only one or very few genebanks and, therefore, failings in those genebanks could mean a complete loss of the collections.

Overall, international collecting missions have become less frequent as a result of increased restrictions posed by national legislation. During the 2011 to 2019 period, almost 250 000 samples were collected by 366 institutes in 87 reporting countries. A number of countries report having strategies in place for targeted collecting and for addressing missing genetic diversity, incomplete ecogeographic coverage and incomplete coverage of targeted taxa, including CWR, as well as for trait-specific gaps, such as those for resistance to pests and diseases. Although the acquisition of germplasm through national collecting has improved, many genebanks could still benefit from more (and more targeted) collecting based on gap analyses. Despite renewed interest in the acquisition of CWR and WFP, the collection and conservation of wild species often fail because of the unavailability of staff specialized in relevant disciplines such as taxonomy and phenology. In the case of both CWR and WFP, *in situ* and *ex situ* conservation need to be better integrated.

Germplasm health issues are becoming increasingly important in the conservation, distribution and use of PGRFA. The increased movement of germplasm within and between countries and continents increases the potential spread of pests and diseases. Overall, awareness of these issues as well as the actual management of germplasm-health issues seem to have improved during the reporting period. However, many national genebanks still lack adequate human and financial resources to properly monitor germplasm health, and these limitations greatly affect germplasm exchange.

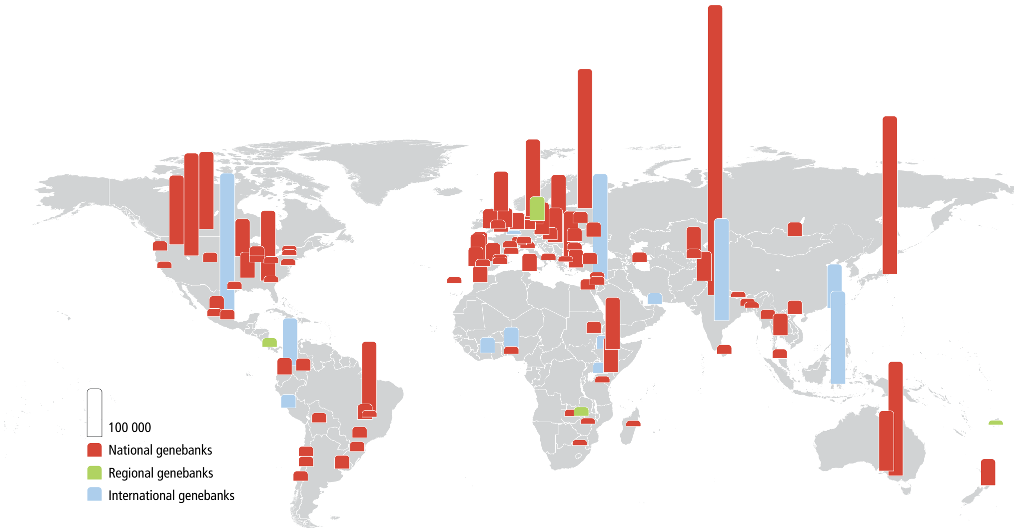
Approximately one-third of the accessions reported by countries were regenerated between 2012 and 2019, while 24 percent are in need of regeneration, which remains one of the main challenges for many countries and genebanks. In particular, the regeneration of several wild PGRFA and out-crossing species is problematic for many genebanks.

Although documentation has been highlighted as an essential part of genebank management for many years, and despite the support provided, including by the Crop Trust, many countries still lack information systems for managing their genebanks and thus struggle to document passport and other genebank management data. With the increasing availability of improved open-source software for genebank data management, such as the new Grin-Global Community Edition (GG-CE), the situation shows signs of improving. Standardized passport data and Data Object Identifiers (DOIs) are increasingly being used for germplasm exchange and for cross-referencing germplasm in publications. Greater efforts are still needed to train data specialists and genebank managers to adopt and use these improved systems.

There is also plenty of room for greater use of barcoding and direct digitalization of data in all areas of genebanking activity. In addition, digitalization of old data from hard copies is still required in some genebanks and should be prioritized before the data are lost. Linking databases to global portals is enhancing germplasm exchange and use but also facilitates compliance with international reporting obligations, such as those for SDG Indicator 2.5.1.a.

National genebanks in 87 reporting countries distributed almost 1.3 million accessions between 2012 and 2019, with well over 90 percent of these distributions made within the respective country. The main recipients included national agricultural research centres, farmers, NGOs and

FIGURE 3.1
Geographical distribution of national genebanks holding more than 6 000 accessions, regional genebanks and international genebanks



Notes: The Nottingham Arabidopsis Stock Centre is not included. *Arabidopsis thaliana* is widely used as a model species for plant biology research. In 2000, it was the first plant to have its genome sequenced. Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
Source: FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)*. [Cited 19 December 2023]. https://www.fao.org/wiews/en/

the private sector.

As of 31 December 2021, materials under the International Treaty's Multilateral System of Access and Benefit Sharing (MLS) totalled over 2.3 million accessions, as reported by 76 Contracting Parties and 15 regional and international centres (Article 15 bodies). The MLS materials of the Contracting Parties and Article 15 bodies account for about 54 percent of their total *ex situ* holdings as reported for SDG Indicator 2.5.1.a.

The number of botanic gardens in the world is more than 3 000, about 20 percent more than the number reported in 2009. Ten countries have more than 100 botanic gardens each. At least 350 botanic gardens in 74 countries have associated seed banks. The expansion of seed banks in botanic gardens has led to an increase in research on the seed physiology of wild species, which is essential for determining seed-storage protocols.

3.3 Acquisition of germplasm

Collecting germplasm in the wild or from farmers' fields is by default the most important means of obtaining genetic diversity for *ex situ* conservation. In the past, collecting efforts were frequently undertaken to obtain regional coverage of a given crop gene pool or to capture crop diversity at large. However, this approach has changed over the years, and there is now a clearer

TABLE 3.1
Extent of different types of gaps in *ex situ* collections

	Total number	*Ex situ* collection gaps (%)			
		Incomplete coverage of targeted taxa, including missing CWR	Missing known FV/LR or historical varieties	Incomplete ecogeographical coverage	Incomplete biotic and abiotic stress resistance coverage
Genera	483	64	32	59	47
Mixed groups	174	72	33	73	26
Genebanks	326	70	55	62	45
Countries	89	93	79	85	65

Notes: Mixed groups include more than one genus or crop group. FV/LR = farmers' varieties/landraces. CWR = crop wild relatives.Data provided by 89 countries.

focus on filling taxonomic and trait-specific gaps in collections and on collecting from areas where target species have not yet been collected.

3.3.1 Germplasm acquired through collecting

Targeted collecting based on gap analyses

The need for targeted collecting is reported for 483 genera and 174 mixed groups[3] conserved in 326 genebanks in 89 countries (Table 3.1). About 82 percent of these genebanks, located in 79 countries, have a strategy in place for identifying gaps in their collections; however only 52 percent (in 61 countries) also have a strategy in place for targeted collecting of the missing diversity.

Incomplete coverage of targeted taxa, including CWR, and incomplete ecogeographical coverage are among the most frequently reported gaps in genebank collections, applying to 66 percent and 62 percent of collections, respectively.[4] FV/LR are, however, relatively well collected: gaps in these groups are reported for only 32 percent of the conserved crop genera.[5] Gaps in the conservation of biotic and abiotic stress resistance traits are reported for 41 percent of collections,[6] leaving scope for further collecting but also for greater use of the available diversity for crop improvement.

Gap analysis has become an important tool for planning targeted collecting missions to fill gaps that can't be filled by accessing material from other genebanks (Ramirez-Villegas *et al*., 2010, 2020). The methodology used to identify gaps is reported to be a comparison of stored material against geographical references. This method was used for almost 70 percent of the 2 608 taxa or groups of taxa for which gaps had been identified. Other frequently used approaches include comparing existing collections with the mandate of the organization or genebank.

Other motivations for collecting

A number of countries report the need to increase the genetic diversity in collections, either from a conservation[7] or from a breeding perspective[8] (including the need for specific traits or characteristics). Jordan reports re-collecting accessions that were collected in farmers' fields 10 or 20 years previously to gather newly adapted

[3] Mixed groups include more than one genus or crop group.
[4] Calculated as the weighted averages of the figures for genera and mixed groups in Table 3.1.
[5] As noted above.
[6] Calculated as the weighted averages of the figures for genera and mixed groups in Table 3.1
[7] For example, Azerbaijan, Brazil, Canada, Czechia, France, Latvia, Lebanon, Myanmar, Niger, Norway, Philippines, South Africa, Zambia.
[8] Azerbaijan, Brazil, Chile, Poland.

genetic diversity. Tajikistan reports collecting materials to replenish accessions with low viability. The loss of accessions from collections is also mentioned.[9] A few countries report specifically on wild species. Armenia mentions collecting threatened wild species. Belarus expresses concern about not being able to represent wild species adequately in its collections. Brazil reports collecting wild species of groundnut. Botswana reports collecting wild species in general. Egypt indicates that 1 percent of its holdings are wild species. Guyana mentions that it has added a wild species of cassava to its collection. Hungary reports collecting wild species used as food plants. Portugal reports that more attention has been paid to wild species in specific ecological areas.

Global collecting efforts

A total of 249 920 collected samples, belonging to 1 216 genera and 3 121 species from 167 botanical families, are reported by 366 institutes in 87 countries (Table 3.2). Collecting efforts were significantly higher during the second reporting period (2014 to 2019) than during the first (2012 to 2014).[10] Additionally, 39 percent of the samples collected during the 2012 to 2014 period were added to medium- and/or long-term storage facilities.[11] During the 2012 to 2019 period, an average of 31 240 samples were collected annually.[12]

Collected samples by crop group

Table 3.3 shows the numbers of collected samples for different crop groups. The crop group with the highest number of collected samples is cereals, which account for 29 percent of all collected samples, followed by vegetables, pulses, fruit plants, forages, oil plants, roots and tubers and fibre plants. The remaining crop groups have fewer than 10 000 samples each, with sugar crops and nuts each having fewer than 1 300 samples.

Comparing these data with those presented in the SoW2 shows that there has been an increase in the proportion of samples of fruit and nut plants[13] (+5 percent), oil plants (+4 percent), roots and tubers (+3 percent), fibre plants (+3 percent) and vegetables (+0.3 percent). It is noteworthy that herbs and spices (including aromatic plants) and medicinal and stimulant plants together accounted for 5 percent of all the collected samples, an increase from the 3 percent figure reported in the SoW2. The share of pulses (or food legumes) among the total samples collected dropped by 7 percent, forages by 8 percent, and cereals and pseudo-cereals[14] by 5 percent. These results show greater overall effort being put into collecting fruit and nut plants, oil plants, fibre plants, and roots and tubers.

Samples collected by region

Collecting activities in the different regions and subregions of the world, as reported by countries, are presented in Table 3.4. Asia is the region with the most collecting activities (54 percent of the total number of samples). By far the largest number of samples were collected in Eastern Asia, which accounted for 46 percent of the total number of samples collected in Asia and 25 percent of those collected worldwide. The figures for Latin America and the Caribbean were 50 982 samples, or 20 percent of the global total.

Similar numbers of samples were collected in Europe and sub-Saharan Africa, in each case around 10 percent of the global total.

Samples collected by country

Among countries, China (59 847 samples), Mexico (22 925), India (15 519), Brazil (9 169) and Ethiopia (7 611) had the highest number of collected samples. Nine countries[15] report having collected

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9 Guyana, Papua New Guinea, Philippines, Romania, Sweden, Tajikistan, Trinidad and Tobago.

10 See Reporting process under Section 1.4.

11 Data on the percentage of collected samples successfully stored under medium- or long-term conditions were not requested for the 2014–2019 period..

12 The SoW2 reported about 20 000 samples collected per year. This figure cannot be fully compared with the current data in view of the discrepancies in the number of countries reporting.

13 Fruit and nut plants were grouped together in the SoW2.

14 Cereals and pseudo-cereals were grouped together in the SoW2.

15 Belarus, Cyprus, India, Iran (Islamic Republic of), Kenya, Mexico, Poland, Portugal, Spain.

TABLE 3.2
Summary of collecting activities, 2012 to 2019

	Reporting periods		Total
	January 2012 to June 2014	July 2014 to December 2019	January 2012 to December 2019
Number of countries	61	79	87
Number of taxa and samples collected			
Families	119	159	167
Genera	598	1 112	1 216
Species	1 234	2 717	3 121
Samples	49 909	200 011	249 920
Average number of samples collected			
Average number of samples collected per year	19 964	36 366	31 240
Average number of samples collected per country per year	327	460	359

TABLE 3.3
Collected samples by crop group, 2012 to 2019

Crop group	All PGRFA			Crop wild relatives			Wild food plants		
	Species (No.)	Samples (No.)	Samples (%)	Species (No.)	Samples (No.)	Samples (%)	Species (No.)	Samples (No.)	Samples (%)
Cereals	101	73 097	29	73	2 236	18	2	13	0
Vegetables	364	30 981	12	126	1 968	16	125	2 502	47
Pulses	100	24 936	10	62	1 050	8		244	5
Fruit plants	364	24 444	10	70	1 076	9	89	1 917	36
Forages	456	17 016	7	163	2 238	18			
Oil plants	35	15 492	6	8	135	1	2	104	2
Roots and tubers	68	11 761	5	34	756	6	3	18	0
Fibre plants	51	10 154	4	10	80	1			
Ornamentals	555	8 058	3	26	65	1			
Herbs and spices	184	4 968	2	36	246	2	49	386	7
Stimulants	20	3 892	2	3	203	2			
Medicinal plants	540	3 699	2	37	130	1			
Pseudo-cereals	29	2 315	1	8	67	1	5	161	3
Material plants	75	2 057	1	2	3	0			
Sugar crops	8	1 284	1	6	153	1	1	1	0
Nuts	20	1 138	1	5	12	0	5	10	0
Other	151	14 628[a]	6	42	2 192[b]	17			
Total	**3 121**	**249 920**	**100**	**711**	**12 610**	**100**	**281**	**5 356**	**100**

Notes: PGRFA = plant genetic resources for food and agriculture.
[a] Mixed aggregations (13 321 samples), wild flora (1 237 samples) and unspecified taxa (47 samples).
[b] Unspecified taxa (1 980 samples). Data provided by 87 countries.

TABLE 3.4
Regional and subregional breakdown of sample collection figures, 2012 to 2019

Regions and subregions	Countries (No.)	Species (No.)	Samples (No.)	Samples (%)	Crop wild relatives		Wild food plants	
					Species (No.)	Samples (No.)	Species (No.)	Samples (No.)
Northern Africa	4	229	4 669	1.9	29	309	19	83
Northern Africa	4	229	4 669	1.9	29	309	19	83
Sub-Saharan Africa	21	389	24 613	9.8	57	636	27	383
Eastern Africa	9	335	13 484	5.4	48	408	23	371
Middle Africa	2	3	344	0.1				
Southern Africa	3	46	546	0.2	4	8	5	9
Western Africa	7	72	10 239	4.1	9	220	1	3
Northern America	1		4 000	1.6				
Northern America	1		4 000	1.6				
Latin America and the Caribbean	15	790	50 982	20.4	78	1 495	41	1 892
Central America	5	636	24 988	10	51	359	28	788
Caribbean	2	92	583	0.2	3	27	2	2
South America	8	133	25 411	10.2	25	1 109	11	1 102
Oceania	2	8	5 193	2.1	2	260	3	413
Melanesia	1	8	718	0.3	2	207	3	413
Australia and New Zealand	1		4 475	1.8		53		
Asia	24	1 616	134 154	53.7	476	6 011	166	1 820
Central Asia	3	50	2 506	1	11	163	5	79
Eastern Asia	3	63	61 577	24.6	8	1 494	1	343
South-eastern Asia	4	133	21 656	8.7	3	199	2	64
Southern Asia	7	1 069	39 766	15.9	185	1 824	115	988
Western Asia	7	577	8 649	3.5	298	2 331	54	346
Europe	20	793	26 309	10.5	179	3 899	61	765
Northern Europe	5	119	1 357	0.5	30	138	9	22
Eastern Europe	5	452	4 973	2	78	419	29	146
Southern Europe	6	413	15 487	6.2	106	1 212	34	528
Western Europe	4	46	4 492	1.8	9	2 130	5	69
Total	**87**	**3 121**	**249 920**	**100**	**711**	**12 610**	**281**	**5 356**

Note: Data provided by 87 countries.

germplasm from more than 150 species. The four countries that collected the most interspecific diversity were India (842 species), Mexico (635), Cyprus (339) and Poland (248).

The genera collected by the largest number of countries include *Zea* (50 countries), *Solanum* (48 countries), *Phaseolus* (41), *Capsicum, Cucurbita* and *Cucumis* (38 countries each) and *Allium* and *Vigna* (37 countries each). *Echeveria* and *Solanum* were the two genera with the highest number of collected species (77 and 76 species, respectively), followed by *Allium* (58 species), *Tillandsia* (50), *Trifolium* (46) and *Vicia* (40). All species of *Echeveria* and *Tillandsia*, which are mainly used for ornamental purposes, were collected in Mexico, whereas the two legume genera *Trifolium* and *Vicia* were collected in 25 and 34 countries, respectively.

A number of countries received support for collecting missions through international projects, especially for the collecting of CWR. The organizations providing this support included the Crop Trust (Box 3.1), the Millennium Seed Bank (MSB) (e.g. in South Africa), the Darwin Initiative (in Madagascar and Zambia), FAO (Technical Cooperation Programme projects in Armenia, Lebanon, Namibia and Zimbabwe), the Islamic Development Bank (in Namibia), the Global Environment Facility (GEF) (in Ecuador), the United Nations Development Programme (UNDP) (in Lebanon), the International Fund for Agricultural Development (IFAD) (in Namibia), the European Union (also in Namibia),the development agency of the United States government (in Kenya) and CGIAR centres (e.g. the International Crops Research Institute for the Semi-Arid Tropics [ICRISAT] in the Niger, the United Republic of Tanzania and Zimbabwe; the International Center for Agricultural Research in the Dry Areas [ICARDA] in Lebanon; the International Rice Research Institute [IRRI] in the United Republic of Tanzania; the International Maize and Wheat Improvement Center [CIMMYT] in Azerbaijan; Bioversity International in Papua New Guinea and South Africa; and the World Vegetable Center [WorldVeg] in Madagascar). Many of the CGIAR centres have also conducted collecting missions in the countries where they are located. The MSB carried out collecting activities in 12 countries, collecting a total of 418 samples of 176 CWR taxa (Elinor Breman, personal communication). Collecting CWR has been facilitated by new tools and reference materials for conservation planning (Magos Brehm *et al*., 2019; Engels and Thormann, 2020).

Collecting crop wild relatives and wild food plants

CWR are wild taxa closely related to crops. They continue to evolve in the wild and as such are locally adapted and represent a potential source of genes and alleles for enhancing crop resilience to changing environmental conditions and human needs. The genetic diversity of CWR is threatened by, *inter alia*, climate change and the occurrence of natural calamities, changes in land use, overgrazing, nitrogen deposition and desertification (FAO, 2017). Additional factors contributing to the genetic erosion of CWR include lack of knowledge about their biology, lack of adequate infrastructure for their *ex situ* cultivation and insufficient funding for their conservation.

WFP consist of a wide range of different species, many of which play an important role in the nutrition and food security of rural communities, particularly during periods of food scarcity. WFP may be closely related to domesticated species; in such cases they are also considered CWR. Their gene pools may, therefore, contribute to the genetic improvement of crops. Likewise, crop gene pools may contribute to their domestication. WFP are threatened by overharvesting, overgrazing, agricultural intensification, the expansion of the agricultural frontiers, increased pesticide use and habitat loss.

Most reporting countries carried out targeted collecting of CWR and WFP. Sixty-two countries report collecting a total of 12 610 CWR samples belonging to 711 distinct species. Fifty countries report collecting a total of 5 356 WFP samples belonging to 281 distinct species. In general, most of the collected WFP species are either vegetables (47 percent of total samples) or fruit plants (36 percent). The average numbers of samples collected per species is similar for CWR and WFP (18 and 19, respectively), which is well below the average number of samples per species for all collected germplasm materials (80 samples per species).

Countries that collected more than 700 CWR samples during the reporting period include Germany (2 120 samples),[16] India (1 587 samples from 162 species), Cyprus (1 016 samples from 233 species), China (881 samples from four species) and Brazil (715 samples from four species).

The genera represented by the largest numbers of collected CWR samples include *Solanum*, with 966 samples or 8 percent of all collected CWR samples, *Oryza* (687 samples), *Aegilops* (541 samples), *Lactuca* (489), *Trifolium* (467), *Manihot* (408), *Medicago* (385), *Actinidia* (335), *Lathyrus* (299) and *Vicia* (288). These ten genera accounted for 39 percent of all collected CWR samples. *Allium* was collected in the largest number of countries (18), followed by *Solanum* (15), *Trifolium* (14), *Aegilops* and *Medicago* (13 each), *Avena*, *Lathyrus* and *Vicia* (12 each), and *Melilotus*, *Malus* and *Hordeum* (11 each).

Countries that collected more than 300 WFP samples include Mexico (788 samples from 28 different species), India (791 samples from 100 species), Chile (555 samples from three species), Ecuador (535 samples from six species), Papua New Guinea (413 samples from three species of *Musa*), Japan (343 samples of wild soybean) and Spain (339 samples from 13 species).

The genera with the largest number of collected WFP samples include *Physalis* (669 in four countries), *Lactuca* (458 in nine countries), *Aristotelia* (437 samples of *A. chilensis*, all collected in Chile), *Musa* (417 samples from four wild species, collected in Papua New Guinea and India), *Vaccinium* (390 samples from five berry-shrub species, collected in seven countries) and *Solanum* (289 samples, collected in seven countries). Samples of edible species of *Allium* were collected in the largest number of countries (12), followed by *Lactuca* (9). The nine highest-ranked WFP genera accounted for 3 271 samples in total (55 percent of all WFP samples collected).

The annual number of accessions of CWR and WFP added to genebanks[17] during the period 1946 to 2020 is shown in Figure 3.2. While the largest annual additions of CWR overall occurred mainly between 1984 and 1993,[18] the rate of addition of these materials to *ex situ* collections has remained relatively high since then. In the case of WFP, there has been a positive trend over the past 40 years, although numbers are significantly lower than for CWR.

It is noteworthy that over 3 880 samples belonging to 135 wild species assigned to the IUCN categories of global major concern (IUCN, 2022), namely Extinct in the Wild, Critically Endangered, Endangered, Vulnerable and Near Threatened, have been collected in 26 countries. Forty-five of these species are CWR and 11 are WFP.

Sub-Saharan Africa

A number of countries[19] report a focus on local minor crops and FV/LR, including roots and tubers, and pulses. The possible loss of genetic diversity via genetic erosion is mentioned by Ghana and the Niger as a reason for collecting. Most of these countries, as well as Madagascar, report collecting CWR and WFP. Madagascar, the United Republic of Tanzania, Zambia and Zimbabwe mention collaboration with international organizations and projects in the collecting of germplasm, including germplasm from some major cereal and pulse crops. Togo reports collecting cocoa with assistance from the International Institute of Tropical Agriculture (IITA).

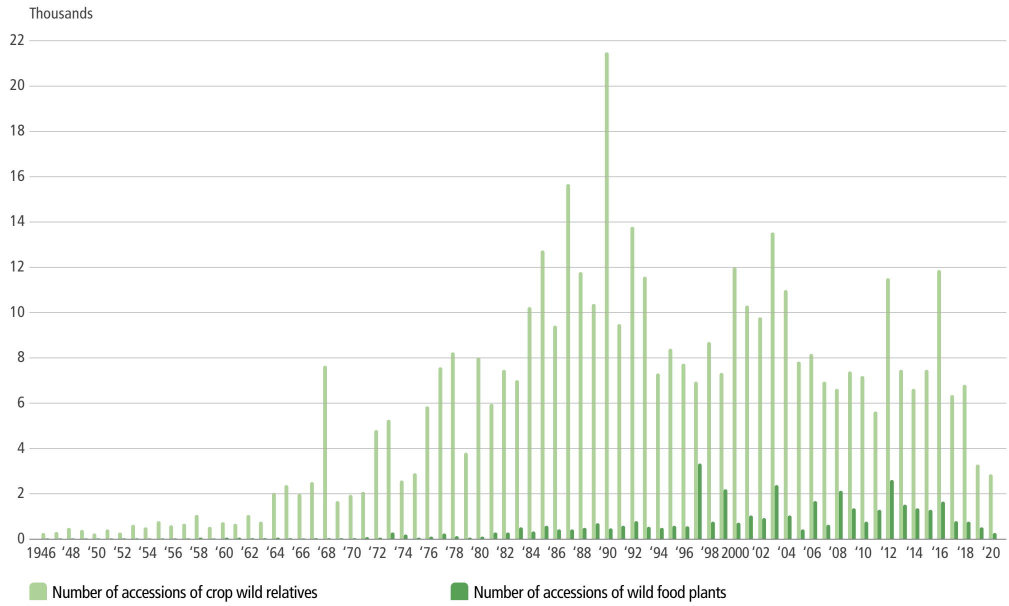
16 Data did not specify taxonomy.

17 Accessions added may have been from collecting missions or from donations (Section 3.3).

18 The peak in 1990 is caused by the incorporation of more than 7 000 accessions of Avena CWR and almost 2 000 of Hordeum CWR into the genebank of the Plant Gene Resources of Canada, as well as more than 1 000 accessions each into the genebanks of the National Small Grains Germplasm Research Facility (USDA), the Western Regional Plant Introduction Station (USDA), ICARDA and CIMMYT.

19 Benin, Botswana, Eritrea, Ethiopia, Ghana, Kenya, Namibia, Mali, South Africa, Uganda, Zambia, Zimbabwe.

FIGURE 3.2
Number of accessions of crop wild relatives (light green) and wild food plants (dark green) added to *ex situ* collections, 1946 to 2020



Notes: Data filtered by acquisition date.
Source: FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)*. [Cited 19 December 2023]. https://www.fao.org/wiews/en/

Northern Africa
Egypt, Tunisia and the Sudan report collecting CWR, the two latter countries indicating that this involved assistance from international centres. Tunisia mentions that its national genebank has used the focused identification of germplasm strategy (FIGS) technique to set ecogeographic collecting priorities. The Sudan mentions training staff on sample collecting with the help of the Crop Trust and MSB. Morocco reports collecting samples from 77 species, many of them spices.

Latin America and the Caribbean
Cuba reports that only 40 percent of its research institutes provided feedback on collecting activities and that *Manilkara* and *Theobroma* were the two most important targeted genera. Trinidad and Tobago reports collecting local crops to better prepare for the impact of climate change and in order to replace accessions lost from the collection.

Among the four reporting countries from Central America, El Salvador, Guatemala and Mexico report collecting CWR. Mexico reports that 40 percent of the 23 000 samples collected were CWR. All three countries also mention local and/or native species of field and horticultural crops. Costa Rica reports collecting samples of maize, beans and rice.

South American countries report collecting a large variety of crops and species. Argentina reports focused collecting of *Prosopis* and *Solanum* gene pools. Chile reports targeting native species such as Chilean guava (*Ugni molinae*) and potato.

Box 3.1

The global crop wild relative project coordinated by the Global Crop Diversity Trust

One important source of collected crop wild relative (CWR) samples has been the Global Crop Diversity Trust project "Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives", which was funded by the Government of Norway and ran from 2011 to 2021 (Crop Trust, 2022). The project covered collecting activities, regeneration of collected samples, evaluation and pre-breeding activities for 19 selected CWR, and also addressed capacity building. The project's collecting activities were based on a comprehensive inventory, a detailed global gap analysis and a priority-setting procedure for selecting the target species. Collecting activities were undertaken between 2013 and 2019 by 47 partner institutions jointly with the Millennium Seed Bank (MSB).

A total of 4 587 seed samples were collected from 25 gene pools selected by scientists from 25 countries across four continents, covering 27 families and at least 355 taxa and 321 species (Eastwood *et al.*, 2022). Eighty-five of the species were new to the MSB, and the seeds of 13 of the taxa had not previously been available under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture.

The materials collected were deposited in 30 genebanks in the partner countries as well as in some additional national genebanks. Duplicates were sent to MSB for long-term conservation. A third subsample consisting of 3 279 unique accessions was sent to six of the CGIAR centres and four national genebanks for regeneration and safety duplication. Backup storage at the Svalbard Global Seed Vault will be the responsibility of the recipients of the third subsample.

Other important outputs from the project include:

- the inventory, which is a comprehensive master list of 1 667 globally important CWR taxa of 173 crops, covering 37 families, 108 genera and 192 species;[a] and
- a searchable, curated occurrence dataset containing 5 647 442 records, including 3 022 064 records for the 29 priority genera and 375 602 records for the 445 priority CWR taxa within these genera.[b]

Source: Crop Trust. 2022. *Crop wild relatives*. In: *Crop Trust*. Bonn, Germany. [Cited 4 June 2022]. https://www.croptrust.org/work/projects/crop-wild-relatives/; Eastwood, R.J., Tambam, B.B., Aboagye, L.M., Akparov, Z.I., Aladele, S.E., Allen, R., Amri, A. *et al*. 2022. Adapting agriculture to climate change: A synopsis of coordinated National Crop Wild Relative Seed Collecting Programs across five continents. *Plants*, 11(14): 1840. https://doi.org/10.3390/plants11141840

[a] Further information at http://www.cwrdiversity.org/checklist

[b] Further information at https://www.cwrdiversity.org/checklist/cwr-occurrences.php

Colombia and Ecuador report collecting local cocoa, *Passiflora* and *Annona* and other fruit-tree species. Guyana mentions that it prioritized native species such as avocado, pineapple and sweet potato, and local breadfruit varieties. Ecuador mentions collecting CWR. Uruguay reports collecting CWR and WFP.

Northern America

Canada was the only country from this region that reported on collecting activities. According to its narrative report,[20] more than 8 500 samples were collected from 218 taxa, predominantly species native to Canada, many of them forages. CWR of *Linum, Helianthus, Lupinus* and *Hordeum* were also collected. In addition, 200 samples of *Avena* were collected as part of the Crop Trust-coordinated Crop Wild Relatives Project, and these were recently added to the global *Avena* base collection maintained by the national genebank. *Lonicera caerulea* (blue-berried honeysuckle) was collected jointly with the N.I. Vavilov All-Russian Institute of Plant Industry (VIR), Saint Petersburg.

Asia

Asia reported the highest number of CWR samples collected. Armenia, Azerbaijan, Jordan and Lebanon report collecting CWR and some local or native field crops and fruit-tree species. In addition to the support provided

[20] These data are not reflected in the database used for the analysis of this section (Table 3.4).

by international organizations, including FAO and MSB, some foreign private companies also supported collecting in a few countries. Jordan mentions re-collecting crops, especially vegetable crops that have been stored for an extended period to capture the effects of more recent evolutionary changes. Yemen indicates that it has been able to collect germplasm materials despite the ongoing war, primarily thanks to project funding from the International Treaty's Benefit-sharing Fund (FAO, 2023b).

All three Central Asian countries that provided country narratives mention the collecting of native crop gene pools, including *Lactuca, Allium, Brassica, Daucus, Hordeum, Aegilops* and *Spinacia turkestanica*. Tajikistan reports genetic erosion in many of its traditional crops and CWR, and that it has conducted targeted collecting missions for cereals, legumes, nuts and fruit-tree species. Uzbekistan reports that it has mainly collected cereals, fruit crops and grapevine, all gene pools with significant local diversity.

Bangladesh and India report a focus on CWR and local minor crop varieties. In India, the need to increase preparedness for climate change has reportedly been an important motive and criterion for prioritizing species. India also mentions that there is a need to collect diversity in Central Asian countries, especially of vegetables and fruits species. Nepal reports adopting a "red listing of landraces" approach as a basis for successfully collecting threatened materials.

Indonesia reports that close cooperation between its extension service and research and university stakeholders has improved collecting activities significantly. Malaysia, Myanmar and the Philippines report that they have collected local rice landrace varieties as well as other crops and CWR. The Philippines notes that it has had to undertake a major re-collecting effort to replace accessions lost because of a fire and flooding at its national genebank and that it has undertaken extensive training of staff at several institutions. It further notes that the dramatic spread of commercial varieties of vegetables, legumes and maize in the country is threatening local PGRFA and that the release of genetically modified maize varieties means that there is an urgent need to collect traditional varieties.

Japan reports that its isolated location relative to the Asian continent means that it has strict quarantine measures for plant materials and that these hamper the collecting and introduction of germplasm from abroad. Mongolia reports collecting native wild species used for pasture, fodder and medicinal purposes.

Oceania

Papua New Guinea reports that it focuses on collecting cultivated and wild banana diversity to fill gaps in its collection and that it has also collected sweet potato and sugarcane samples.

Europe

Relatively limited collecting activities were reported from this region, although in terms of numbers of CWR samples collected Europe ranks second after Asia. Portugal reports that it focuses on vegetatively propagated species, namely fruit and olive trees, grapevines and hops. It also mentions that more importance has been given to CWR and to threatened species, and that more training is needed. Serbia mentions that it has been able to identify some collection gaps and to fill these through targeted collecting. Spain reports that most of the institutes that answered an internal survey have strategies in place for filling gaps identified in their collections.

Most Eastern European countries report collecting species for which gaps in collections have been identified. Czechia mentions that it has identified diversity hotspots as part of its priority-setting activities and has carried out five CWR missions. Hungary, Poland, the Republic of Moldova and Romania also report targeted collecting of CWR species. In the Republic of Moldova, this was done on the basis of an inventory of CWR in forest ecosystems. Romania reports that its national genebank has carried out collecting missions for vegetables in Bulgaria and the Republic of Moldova.

Most Northern European countries report collecting efforts focused on local and minor crops and forage species. Finland, Norway and Sweden mention collecting activities aimed at addressing identified gaps and/or increasing the geographical representation of taxa in their collections. Norway and Sweden report re-collecting accessions that have been lost or need to be replaced. Denmark, Estonia, Finland, Germany, the Kingdom of the Netherlands, Norway, Sweden, Switzerland and the United Kingdom report collecting CWR.

The Kingdom of the Netherlands reports that its national genebank, the Centre for Genetic Resources (CGN), has carried out international collecting missions in Armenia (asparagus and lettuce), Azerbaijan (asparagus and lettuce), Uzbekistan (carrot, melon and lettuce), Kyrgyzstan (carrot) and Jordan (lettuce). France mentions that botanic gardens have conducted focused collecting of genetic resources that are threatened with extinction. Germany reports that more than 400 advanced cultivars were deposited in its national genebank after they lost variety protection status.

International research centre genebanks

The 11 CGIAR international agricultural research centres and WorldVeg report collecting 22 327 samples of more than 30 crops or crop gene pools in 34 countries in five regions during the reporting period. In many instances, these collecting activities were undertaken by the respective country's national agricultural research system. The centre that collected the most samples was ICARDA (a total of 6 614 samples of ten crop gene pools in three regions), followed by ICRISAT (a total of 6 210 samples of three crop gene pools in three African countries), IITA (a total of 4 321 samples of six crop gene pools in three African countries) and AfricaRice (1 996 samples of one crop gene pool in eight African countries). Two centres (CIMMYT and the International Livestock Research Institute [ILRI]) did not conduct any collecting themselves but participated, along with six other centres, in the Crop Wild Relatives Project coordinated by the Crop Trust and supported by the Government of Norway. IRRI did not actively participate in collecting missions but reports that it received samples collected under the Crop Wild Relatives Project.

The regional origin of the samples collected by the international centres is as follows: sub-Saharan Africa – 13 993 samples or 63 percent of the total; Europe – 3 761 samples or 17 percent; Asia – 3 340 samples or 15 percent; Latin America and the Caribbean – 631 samples or 3 percent; Northern Africa – 400 samples or 2 percent; and Oceania – 202 samples or 1 percent. It should be noted that 22 percent of the samples were collected in the countries where the respective international research centres are located.

3.3.2 Germplasm acquired via donations and other means

In addition to acquisition through collecting, germplasm samples can also be acquired by genebanks through exchange with other genebanks or institutions, through accession management (for instance by splitting mixed accessions into uniform components) or from research and breeding programmes (single seed descent populations, breeding lines, etc.).

Country and international situation

Eight countries report germplasm acquisition activities other than through collecting, for example through repatriation of lost materials (Botswana, Estonia, Lebanon, Togo and Tunisia), accepting breeding materials from researchers, receiving traditional varieties from farmers' groups (Belarus and Finland) and through donations of materials from other institutions in the country (from public research programmes [Canada] and advanced cultivars from the Federal Plant Variety Office [Germany]). Between 2009 and 2022, the genebanks of the CGIAR, WorldVeg and the International Center for Biosaline Agriculture (ICBA) added more than 132 000 accessions to their holdings that they received through collecting or through donations. Of these, 9 percent are wild samples, 44 percent are FV/LR and the others are research materials, improved varieties and germplasm of unknown biological status. Over the same period, the genebanks of the Nordic Genetic Resource Center, the Centre for Pacific Crops and Trees (CePaCT), and SADC added 5 070, 1 020 and 652 accessions, respectively, to their holdings.

3.3.3 Summary assessment

The number of samples collected per year increased from 20 000 during the reporting period for the SoW2 to more than 31 000 samples during the SoW3 reporting period. Many countries report that collecting has focused on vegetables, fruit plants, ornamentals, herbs and spices, and medicinal plants, including FV/LR or wild species. More than 3 000 distinct species were collected during the reporting period.

Collecting efforts over the reporting period show a clear trend towards national rather than international activity. The trend away from international collecting may have been caused by the increasing restrictiveness and complexity of the legal requirements that non-national entities must meet if they intend to collect genetic material within a country.

Overall, the number of species of CWR and WFP collected declined over the past decade, although interest has increased, especially because of initiatives such as the above-mentioned project coordinated by the Crop Trust. These efforts have also improved the quality of CWR and WFP collecting. However, many countries still have problems carrying out targeted collecting without technical and scientific assistance and financial support.

Acquisitions through donations and other means were not well reported, and information on them is limited. However, some countries report receiving accessions through repatriation and donations from farmers' groups, breeding programmes and other institutions. The CGIAR genebanks received a substantial number of accessions through donations, but specific details are not available.

3.4 Types and status of *ex situ* collections

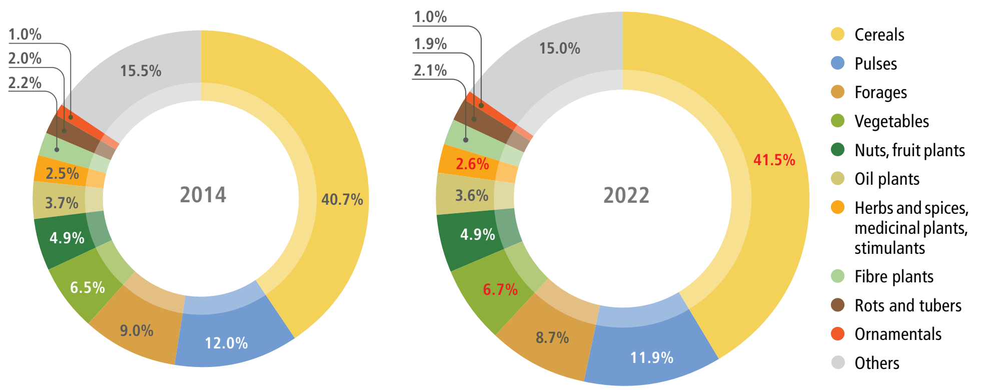
3.4.1 National and international genebanks

According to the report of SDG Indicator 2.5.1.a, 5 941 616 accessions from 7 320 genera and 51 509 species are conserved in *ex situ* collections by 116 countries, four regional genebanks and 13 international genebanks. National genebanks hold 84 percent of all germplasm conserved, the international centres hold 15 percent and the regional centres hold one percent. Accession holdings in 2022 reflect an increase of 10 percent over 2014 (Figure 3.3). Overall, the increase was distributed roughly equally among the different crop groups.

The holders of the five largest *ex situ* collections of selected crops and the percentage increases between 2014 and 2022 are shown in Table 3.5. The crops with the largest number of accessions maintained *ex situ* are wheat, rice and barley, with a combined total of almost 1.7 million accessions. Global holdings for *Triticum* grew by 19 percent between 2014 and 2022. CIMMYT holds the largest share globally (19 percent; 145 039 accessions), while the Australian Grains Genebank, Agriculture Victoria (AGG Australia) holds the largest national collection with 84 464 accessions (11 percent of the total). IRRI holds 26 percent of the global total for rice (over 132 500 accessions), while the National Bureau of Plant Genetic Resources (NBPGR), India, has the largest national collection with 112 593 accessions (22 percent of the total). The increase in global rice holdings between 2014 and 2022 was 9 percent. Plant Gene Resources of Canada (PGRC), AGG Australia and the National Small Grains Collection (NSGC), the United States, together have 30 percent of global barley holdings (a combined 118 766 accessions), while ICARDA holds 8 percent (32 482 accessions).

Other large international cereal holdings include ICRISAT's collections of sorghum (25 percent of global holdings), pearl millet (49 percent) and finger millet (24 percent). The largest national collection of sorghum is held by

FIGURE 3.3
Contribution of crop groups to total *ex situ* collections in 2014 and 2022



Notes: Number of accessions in 2014 = 5 384 351 and in 2022 = 5 941 616. 2022 percentages that are higher than the 2014 equivalents are shown in red.
Source: Elaborated from FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)*. [Cited 19 December 2023]. https://www.fao.org/wiews/en/

the Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, Georgia, the United States (45 794 accessions), and the largest collection of pearl millet by NBPGR, India (8 482 accessions). The global totals for these crops increased by 15 percent and 21 percent, respectively, between 2014 and 2022.

CGIAR genebanks conserve global collections of major staple crops and are therefore often repositories for the largest numbers of accessions for these species. Bioversity International maintains almost 1 700 accessions of banana, 26 percent of global holdings. CIAT holds the largest bean and cassava collections. In addition to the largest collection of *Triticum*, CIMMYT also maintains the largest holding of maize, with just over 32 000 accessions (14 percent of global holdings). The International Potato Center (CIP) has the largest holdings of potato (8 390 accessions) and sweet potato (6 281 accessions). ICARDA maintains the largest collections of broad bean and lentil, the fifth largest holding of wheat and the fourth largest of pea. In addition to sorghum, pearl millet and finger millet, ICRISAT also conserves the largest collections of chickpea and groundnut as well as the second largest collection of pigeonpea. IITA holds the largest cowpea and yam collections worldwide and the second largest cassava collection. Another international centre, WorldVeg, conserves the largest collections of tomato, capsicum and winged bean, and the second largest collection of eggplant. CePaCT holds the world's largest collection of taro (31 percent of total germplasm).

For the other food crops listed in Table 3.5, the largest collections are held by national genebanks. For example, the largest collection of oats is in Canada, pea in Australia, cucurbits in Brazil, pigeonpea in India, teff (millet) in Ethiopia, lettuce in the United States and the Kingdom of the Netherlands, olives in Italy, grapes in Portugal, common millet and prunus in the Russian Federation, and soybean, apple, hazelnut, mango and pistachio in the United States. The largest collections of sunflower are found in the United States, France, the Russian Federation, Brazil and India. The largest collections of sugar beet are in the United States, Germany, Japan, Poland and Hungary. The largest sugarcane holdings are in Cuba, Japan, Colombia, Bangladesh and the

United States. The largest national collections of coffee are found in Ethiopia, France, Ecuador and Portugal. The regional Center for Tropical Agricultural Research and Higher Education (CATIE) holds the second largest collections of coffee and cocoa, with 19 percent and 15 percent of global holdings, respectively, as well as the largest collection of peach palm (44 percent of global holdings).

The "other crops" category includes fibre and forages. Three institutes in Uzbekistan hold 17 percent, 14 percent and 9 percent of the global holdings of cotton, respectively. The United States conserves 15 percent and NBPGR India conserves 14 percent of global cotton accessions. The largest national collections of forage crops are held in Australia (clover and medicago) and Poland (fescue and orchard grass).

Germplasm holdings in national genebanks

According to the 2022 report on SDG Indicator 2.5.1.a, 4 976 565 accessions are conserved in collections under medium- and long-term storage conditions in national genebanks[21] in 116 countries. These accessions represent 7 281 genera and 50 990 species from 394 families. Appendix 1 provides an overview of national holdings, including the total number of genera and species.

Ten countries hold more than 100 000 accessions (Table 3.6).[22] The United Kingdom, the United States, Germany, Australia, Spain and Kenya conserve the highest levels of taxonomic diversity. Eighteen genebanks in 13 countries[23] conserve more than 1 000 species, ranging from 1 090 to 4 233. In addition to these, by far the largest number of species (34 834) are conserved by the MSB at the Royal Botanic Gardens, Kew, United Kingdom. Although this collection mainly focuses on the world's wild flora, it includes numerous CWR and WFP.

It is important to note that 44 percent (22 631) of all species conserved worldwide are represented by only one accession and that only 14 percent (7 203) are represented by ten or more accessions. Furthermore, 4 871 accessions maintained in 73 national genebanks and 185 accessions in four international and one regional genebank have not been taxonomically classified. About 111 870 accessions maintained in 369 genebanks have been taxonomically classified/identified at the genus level only. Of these, more than 100 950 accessions are in 327 national genebanks, with the others in regional and international genebanks (1 525 and 9 395 accessions, respectively). Among samples from wild plants, taxonomic identification at the species level is lacking for 21 264 accessions belonging to 1 368 genera in 198 national genebanks, 64 accessions belonging to 14 genera in three regional genebanks, and 5 002 accessions belonging to 185 genera in ten international genebanks.

Europe has the largest number of genebanks (445 or 52 percent), followed by Latin America and the Caribbean (203 or 24 percent) and Asia (104 or 12 percent). Sub-Saharan Africa has 54 genebanks (6 percent), Northern America 30 (4 percent), Oceania 11 (1 percent) and Northern Africa five (1 percent) (Table 3.7).

Germplasm holdings in international genebanks

The genebanks of the CGIAR international centres (AfricaRice, Bioversity International, CIAT, CIMMYT, CIP, ICARDA, ICRISAT, IITA, ILRI, IRRI and the World Agroforestry Center [ICRAF]), WorldVeg and ICBA manage germplasm collections on behalf of the world community. These collections consist predominantly of materials that are in the public domain and under legal arrangements with the International Treaty, and they largely represent species that are included in the International Treaty's Annex 1.

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[21] SDG Indicator 2.5.1.a monitors all accessions in base collections conserved in medium-term or long-term conservation facilities, and unique accessions stored in active collections under medium-term or long-term conditions that will eventually become part of national base collections.

[22] The numbers reported for the United Kingdom include the specialized research collection held at the Nottingham Arabidopsis Stock Centre.

[23] Australia, Belgium, Bulgaria, Germany, Greece, India, Israel, Kenya, New Zealand, Poland, Russian Federation, Spain, United States.

TABLE 3.5

Holders of five largest *ex situ* collections of selected crops, and percentage increases between 2014 and 2022

Genus (crop)	Total world accessions	Increase from 2014 to 2022 (%)	Major holders ranked									
			1	%	2	%	3	%	4	%	5	%
Triticum (wheat)	783 917	19	CIMMYT (MEX002)	18	AGG (AUS165)	11	NSGC (USA029)	8	INRA CRRAS (MAR088)	6	ICARDA (LBN002)	5
Oryza (rice)	500 818	9	IRRI (PHL001)	26	NBPGR (IND001)	22	NARO (JPN183)	8	DB NRRC (USA970)	7	GB-DOA (THA300)	5
Hordeum (barley)	396 962	9	PGRC (CAN004)	11	AGG (AUS165)	10	NSGC (USA029)	9	ICARDA (LBN002)	8	IPK (DEU146)	6
Zea (maize)	231 918	9	CIMMYT (MEX002)	14	NC7 (USA020)	9	VIR (RUS001)	6	BPGV-INIAV (PRT001)	5	NBPGR (IND001)	5
Sorghum (sorghum)	190 395	15	ICRISAT (IND002)	26	S9 (USA016)	25	NBPGR (IND001)	14	EBI (ETH085)	5	AGG (AUS165)	4
Phaseolus (bean)	186 748	6	CIAT (COL003)	20	W6 (USA022)	9	CNPAF (BRA008)	9	IPK (DEU146)	5	CENARGEN (BRA003)	4
Glycine (soybean)	117 835	6	SOY (USA033)	19	NARO (JPN183)	12	CNPSO (BRA014)	12	AVRDC (TWN001)	12	CENARGEN (BRA003)	8
Avena (oat)	115 596	4	PGRC (CAN004)	25	NSGC (USA029)	18	VIR (RUS001)	9	AGG (AUS165)	4	IPK (DEU146)	4
Cicer (chickpea)	98 242	11	ICRISAT (IND002)	21	AGG (AUS165)	17	ICARDA (LBN002)	16	NBPGR (IND001)	15	W6 (USA022)	7
Vitis (grape)	85 886	12	ISA (PRT018)	30	INRAe-VASSAL (FRA139)	9	DAV (USA028)	4	IMIDRA (ESP080)	4	IVM (UKR050)	4
Trifolium (clover)	82 037	4	APG (AUS167)	25	AGRESEARCH (NZL001)	13	IBERS-GRU (GBR016)	8	ICARDA (LBN002)	7	VIR (RUS001)	6
Medicago (medicago)	80 372	7	APG (AUS167)	34	ICARDA (LBN002)	12	W6 (USA022)	11	VIR (RUS001)	5	INRA CRRAS (MAR088)	4
Lathyrus (pea)	72 569	10	AGG (AUS165)	8	W6 (USA022)	7	IPK (DEU146)	6	ICARDA (LBN002)	5	NBPGR (IND001)	5
Gossypium (cotton)	71 767	8	UzRICBSP (UZB036)	17	COT (USA049)	14	IGPEB (UZB001)	14	NBPGR (IND001)	14	UzRIPI (UZB006)	9
Solanum (tomato)	71 061	16	AVRDC (TWN001)	14	NE9 (USA003)	9	IPK (DEU146)	7	GSLY (USA176)	6	BGUPV (ESP026)	4
Arachis (groundnut)	69 520	15	ICRISAT (IND002)	32	NBPGR (IND001)	20	S9 (USA016)	14	CENARGEN (BRA003)	6	UzRIPI (UZB006)	3
Vigna (cowpea)	60 460	12	IITA (NGA039)	29	S9 (USA016)	14	CENARGEN (BRA003)	8	NBPGR (IND001)	7	NARO (JPN183)	5
Cenchrus (pearl millet)	59 115	21	ICRISAT (IND002)	49	NBPGR (IND001)	14	PGRC (CAN004)	6	ARC (SDN002)	5	S9 (USA016)	4
Solanum (potato)	57 923	6	CIP (PER001)	15	IPK (DEU159)	11	NR6 (USA004)	10	VIR (RUS001)	10	AGROSAVIA (COL017)	5
Malus (apple)	50 946	3	GEN (USA167)	12	VIR (RUS001)	7	PSR (CHE063)	5	NFC (GBR030)	4	NARO (JPN183)	4
Capsicum (capsicum)	50 942	19	AVRDC (TWN001)	17	S9 (USA016)	10	NBPGR (IND001)	9	NARO (JPN183)	6	IPGR (BGR001)	4
x *Triticosecale* (wheat)	45 799	8	CIMMYT (MEX002)	36	VIR (RUS001)	9	IR (UKR001)	8	IHAR (POL003)	5	NSGC (USA029)	4
Lens (lentil)	43 932	10	ICARDA (LBN002)	33	AGG (AUS165)	14	W6 (USA022)	7	NBPGR (IND001)	6	VIR (RUS001)	6
Aegilops (wheat)	38 485	7	ICCI-TELAVUN (ISR003)	20	ICARDA (LBN002)	13	VIR (RUS001)	9	NARO (JPN183)	6	NSGC (USA029)	6
Panicum (millet)	38 104	7	VIR (RUS001)	24	NARO (JPN183)	22	UDS (UKR008)	13	NBPGR (IND001)	9	GeRRI (KEN212)	6
Prunus (prunus)	37 410	-6	VIR (RUS001)	8	CREA-OFA-RM (ITA378)	6	DAV (USA028)	4	NBS (UKR036)	4	UzRIPI (UZB006)	4
Vicia (broad bean)	34 583	11	ICARDA (LBN002)	15	IPK (DEU146)	5	AGG (AUS165)	5	IBERS-GRU (GBR016)	2	EBI (ETH085)	2

Genus (crop)	Total world accessions	Increase from 2014 to 2022 (%)	Major holders ranked									
			1	%	2	%	3	%	4	%	5	%
Cucurbita (cucurbita)	34 260	14	CNPH (BRA012)	8	CATIE (CRI085)	6	AVRDC (TWN001)	4	CENARGEN (BRA003)	4	S9 (USA016)	4
Eleusine (finger millet)	31 846	8	ICRISAT (IND002)	46	NBPGR (IND001)	38	GeRRI (KEN212)	4	EBI (ETH085)	3	PGRC (UGA132)	1
Cajanus (pigeonpea)	29 734	4	NBPGR (IND001)	38	ICRISAT (IND002)	24	GeRRI (KEN212)	10	AGG (AUS165)	6	CENARGEN (BRA003)	3
Helianthus (sunflower)	26 880	11	NC7 (USA020)	20	INRAe (FRA015)	8	VIR (RUS001)	8	CENARGEN (BRA003)	7	NBPGR (IND001)	6
Festuca (fescue)	25 853	3	IHAR (POL003)	16	NARO (JPN183)	11	W6 (USA022)	10	IPK (DEU271)	9	VIR (RUS001)	8
Dactylis (grasses)	21 244	1	IHAR (POL003)	29	NARO (JPN183)	11	IPK (DEU271)	9	W6 (USA022)	8	AGRESEARCH (NZL001)	6
Ipomoea (sweet potato)	19 171	-2	CIP (PER001)	33	NARO (JPN183)	19	S9 (USA016)	6	CNPH (BRA012)	6	INIVIT (CUB006)	5
Solanum (eggplant)	17 855	13	NBPGR (IND001)	25	AVRDC (TWN001)	20	NARO (JPN183)	8	S9 (USA016)	5	PGRRI (GHA091))	3
Manihot (cassava)	17 682	3	CIAT (COL003)	34	IITA (NGA039)	18	CNPMF (BRA004)	13	INIA-EEA DONOSO (PER034)	4	INIVIT (CUB006)	4
Lactuca (lettuce)	16 291	7	W6 (USA022)	16	CGN (NLD037)	16	HRIGRU (GBR006)	9	CRI (CZE122)	9	IPK (DEU146)	7
Beta (sugar beet)	12 319	3	W6 (USA022)	22	IPK (DEU146)	19	NARO (JPN183)	7	IHAR (POL003)	6	NODiK (HUN003)	4
Chenopodium (chenopodium)	11 546	24	EE-Toralapa INIAF (BOL317)	33	EEA Illpa-Puno (PER014)	17	ICBA (ARE003)	11	IPK (DEU146)	9	DENAREF (ECU023)	8
Saccharum (sugar cane)	11 187	-11	INICA (CUB041)	30	NARO (JPN183)	15	CENICAÑA (COL115)	14	BSRI (BGD015)	11	MIA (USA047)	9
Coffea (coffee)	10 465	7	EBI (ETH085)	43	CATIE (CRI134)	19	IRD (FRA254)	8	EETP (ECU330)	5	ISA (PRT018)	5
Dioscorea (yam)	10 372	48	IITA (NGA039)	57	PGRRI (GHA091)	11	INRAe-ANTILLE (FRA109)	5	PRC (VNM049)	3	CePaCT (FJI049)	3
Eragrostis (millet)	9 741	11	EBI (ETH085)	51	W6 (USA022)	14	GeRRI (KEN212)	11	IGB (ISR002)	4	ICBA (ARE003)	4
Theobroma (cocoa)	8 163	16	EETP (ECU330)	27	CATIE (CRI142)	15	DENAREF (ECU023)	7	CIRAD (FRA014)	6	AGROSAVIA (COL032)	6
Musa (banana)	6 377	14	ITC (BEL084)	26	BPI-DNCRDC (PHL024)	7	IITA (NGA039)	6	INIVIT (CUB006)	6	CIRAD-FLHOR (FRA201)	6
Colocasia (taro)	4 169	31	CePaCT (FJI049)	31	PRC (VNM049)	30	PGRRI (GHA091)	7	NARO (JPN183)	6	MRC Bubia (PNG041)	5
Olea (olive)	2 904	12	CREA-OFA-REN (ITA401)	34	IFAPACOR (ESP046)	15	INIAV-Elvas (PRT196)	9	CRFSA (ITA443)	7	BNG (TUN029)	6
Corylus (nut)	2 338	11	COR (USA026)	35	IRTAMB (ESP014)	11	IFG (BLR017)	9	KPS (UKR046)	8	FTGRÍ (AZE009)	7
Mangifera (mango)	1 862	31	MIA (USA047)	16	CPAMN (BRA142)	7	ISOPlexis (PRT102)	7	CPATSA (BRA017)	7	ICIA (ESP048)	5
Psophocarpus (winged bean)	1 607	37	AVRDC (TWN001)	18	NBPGR (IND001)	14	IITA (NGA039)	12	S9 (USA016)	11	AGG (AUS165)	11
Bactris (peach palm)	1 403	32	CATIE (CRI134)	44	AGROSAVIA (COL096)	13	ICRAF (KEN023)	11	INIA-EEA.SR. (PER016)	8	CNPSO (BRA014)	7
Pistacia (pistachio)	748	-10	DAV (USA028)	29	BNG (TUN029)	25	RBG (GBR004)	7	CREA-OFA-RM (ITA378)	6	IGB (ISR002)	6

Note: Holder acronyms are explained in Appendix 5.

TABLE 3.6

Countries conserving the ten largest numbers of accessions, genera or species

Country	Genebanks	Accessions	Genera	Species
United Kingdom	10	847 653 (1)	5 885 (1)	35 284 (1)
United States	27	584 724 (2)	2 532 (2)	13 362 (2)
India	1	424 812 (3)	828 (4)	1 793 (9)
Australia	2	297 198 (4)	557 (13)	2 950 (4)
Japan	1	227 052 (5)	355 (28)	989 (22)
Brazil	26	208 129 (6)	565 (11)	1 746 (10)
Russian Federation	1	200 717 (7)	216 (39)	1 158 (17)
Germany	48	183 662 (8)	812 (6)	3 427 (3)
Canada	3	120 975 (9)	294 (32)	1 059 (18)
Ukraine	55	107 675 (10)	500 (14)	1 522 (13)
Spain	38	78 782 (12)	746 (7)	2 530 (5)
Mexico	59	78 336 (13)	559 (12)	1 973 (8)
Bulgaria	3	69 623 (17)	575 (10)	1 696 (11)
Kenya	1	51 405 (21)	1 013 (3)	2 525 (6)
Israel	3	27 239 (34)	680 (9)	1 628 (12)
Greece	13	9 570 (54)	696 (8)	1 468 (14)
Belgium	12	9 311 (55)	825 (5)	1 983 (7)

Note: Numbers in parenthesis indicate the country ranking in terms of accessions, genera and species conserved.

Germplasm holdings in international genebanks total 906 949 accessions from 673 genera and 3 323 species from 205 countries and territories of origin. The CGIAR collections of CIMMYT (maize, wheat), ICARDA (dryland cereals, grain legumes, temperate forages), ICRISAT (sorghum, millets, grain legumes) and IRRI (rice) all conserve more than 100 000 accessions each. The CGIAR genebanks hold 823 080 accessions of 571 genera and 2 995 species from 202 countries and territories of origin.

The WorldVeg genebank maintains the world's largest public vegetable germplasm collection, which has 68 727 accessions belonging to 140 genera and 325 species from 146 countries. WorldVeg holds the world's largest collections of *Solanum* (14 377 accessions, including tomato and eggplant) and *Capsicum* (8 548 accessions) and the fourth largest collection of *Glycine* (13 794 accessions). The ICBA genebank focuses on germplasm with a proven or potential salinity tolerance and comprises 15 142 accessions belonging to 96 genera and 277 species from 159 countries. The centre holds the third largest *Chenopodium* collection (1 306 accessions) worldwide.

Germplasm holdings in regional genebanks

Many regional genebanks maintain important collections. Examples of such institutions include the following.

- The Nordic Genetic Resource Center (NordGen) conserves 33 306 seed samples from a range of crops, comprising 212 genera and 432 species from 81 countries. Wild materials represent 22 percent of its holdings, FV/LR 12 percent and advanced cultivars 14 percent; the others are research materials.

TABLE 3.7
Number of national genebanks, accessions, genera and species stored, by region and subregion

Regions and subregions (number of countries)	Accessions	Genera	Species	Genebanks
Northern Africa (5)	130 391 (3%)	649	1 431	5 (1%)
Northern Africa (5)	130 391	649	1 431	5
Sub-Saharan Africa (23)	214 871 (4%)	1 375	3 640	54 (6%)
Eastern Africa (9)	167 020	1 075	2 767	25
Southern Africa (5)	16 449	455	857	7
Western Africa (9)	31 402	294	470	22
Northern America (2)	705 699 (14%)	2 555	13 544	30 (4%)
Northern America (2)	705 699	2 555	13 544	30
Latin America and the Caribbean (19)	476 387 (10%)	1 432	5 049	203 (24%)
Central America (7)	85 907	641	2 122	90
Caribbean (2)	20 522	386	714	19
South America (10)	369 958	992	3 010	94
Oceania (3)	336 282 (7%)	759	3 690	11 (1%)
Melanesia (1)	2 940	35	40	8
Australia and New Zealand (2)	333 342	738	3 661	3
Asia (26)	1 041 069 (21%)	1 770	5 981	104 (12%)
Central Asia (3)	75 582	117	269	10
Eastern Asia (2)	246 645	359	1 009	2
South-eastern Asia (6)	98 241	330	563	38
Southern Asia (7)	523 330	957	2 178	31
Western Asia (8)	97 271	1 020	3 428	23
Europe (37)	2 071 866 (42%)	6 307	40 494	445 (52%)
Northern Europe (9)	861 757	5 890	35 354	63
Eastern Europe (10)	667 893	1 056	4 576	136
Southern Europe (12)	236 465	1 207	4 511	125
Western Europe (6)	305 751	1 364	5 418	121
Total	4 976 565	7 281	50 990	852

- CATIE conserves about 6 120 orthodox seed accessions belonging to 58 genera and 91 species, and about 4 800 field genebank accessions belonging to 159 genera and 230 species, including coffee, cocoa and fruit trees. It holds the second largest collections of *Cucurbita* (2 114 accessions), *Coffea* (1 990 accessions) and Theobroma (1 242 accessions). Germplasm held at CATIE originated from 72 countries, and 87 percent of it comprises FV/LR.
- The Southern African Development Community Plant Genetic Resources Centre (SPGRC) genebank maintains approximately 11 326 accessions belonging to 41 species in its base collection deposited by its 12 member countries. About 98 percent of its holdings are FV/LR.

- CePaCT ensures efficient long-term conservation of a broad range of genetic diversity of key food crops in the Pacific region, mostly in the form of *in vitro* collections. These comprise 2 520 accessions of 18 genera and 23 species from 54 countries, including taro, yam, sweet potato and coconut. Its *Colocasia* collection is the largest in the world (1 303 accessions) and its *Dioscorea* collection is the fourth largest (356 accessions). The germplasm conserved at CePaCT comprises FV/LR (89 percent) and research materials (11 percent).

3.4.2 Source of samples in genebanks

Country of origin is known for approximately 77 percent of the 4 292 070 accessions in national genebank holdings (excluding the Nottingham Arabidopsis Stock Centre). Of these, about 40 percent originated in the country where the collection is maintained (Table 3.8). Country of origin is documented for 88 percent of all wild materials conserved, 91 percent of FV/LR and 78 percent of advanced cultivars.

Aside from the country of origin, the source of germplasm in collections was known for about 59 percent of holdings in both 2014 and 2022. Over the period between these dates, the largest variations occurred in the relative importance of germplasm sourced from wild habitats (–2.7 percent), from seed companies (–1.7 percent) and from institutes, experimental stations, research organizations and genebanks (+4.0 percent), reflecting increased exchange of

TABLE 3.8

Number of accessions conserved in national genebanks by subregion, and percentage of accessions that originated in the country where the collection is held

Region	Subregion	Total number of accessions*	Percentage originating in the country where held
Northern Africa	Northern Africa	130 391	57.2
Sub-Saharan Africa	Eastern Africa	167 020	82.5
	Southern Africa	16 449	99.7
	Western Africa	31 402	86.1
Northern America	Northern America	705 699	24.0
Latin America and the Caribbean	Central America	85 907	95.1
	Caribbean	20 522	51.0
	South America	369 958	36.8
Oceania	Melanesia	2 940	83.9
	Australia and New Zealand	333 342	13.9
Asia	Central Asia	75 582	18.6
	Eastern Asia	246 645	0.6
	South-eastern Asia	98 241	71.1
	Southern Asia	523 330	73.8
	Western Asia	97 271	94.1
Europe	Northern Europe	177 262	14.4
	Eastern Europe	667 893	25.7
	Southern Europe	236 465	65.1
	Western Europe	305 571	25.2
World		**4 292 070**	**39.5**

Note: *The collection held by the Nottingham Arabidopsis Stock Centre is excluded.

germplasm between conservation and research centres (Figure 3.4).

3.4.3 Biological status of crop germplasm accessions stored in genebanks

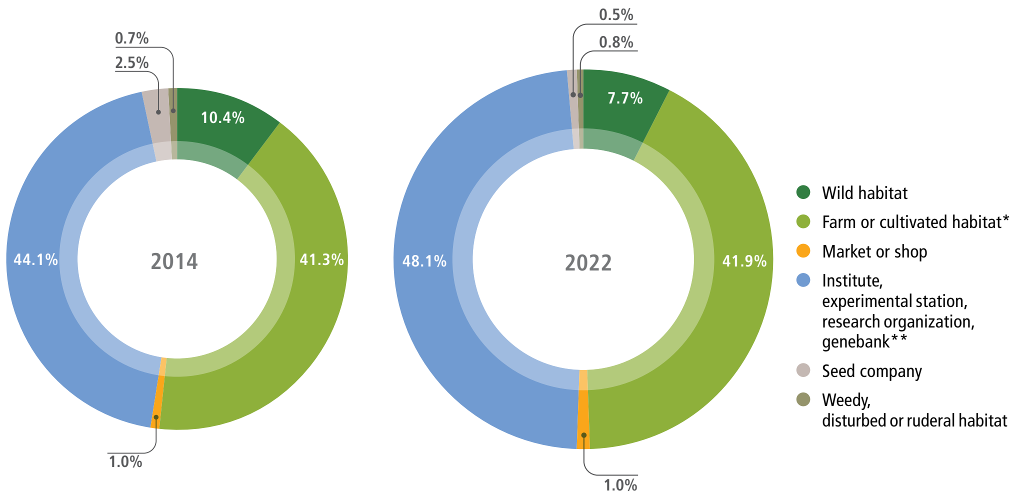
The following categories are used to report the biological status of germplasm: wild samples (populations) from nature; FV/LR; breeding or research materials; and advanced cultivars (Alercia, Diulgheroff and Mackay, 2015; Alercia *et al*., 2020). Figure 3.5 shows the proportions of the biological-status categories among the *ex situ* germplasm collections reported in 2014 and 2022.

Table 3.9 presents data on the biological status of samples maintained in national genebanks (summarized by region) and in regional and international genebanks. On average, biological status is documented for 72 percent of the accessions conserved, ranging from 51 percent in Latin America and the Caribbean to 88 percent in Northern Africa, and from 90 percent in international centres to 98 percent in regional centres.

Wild materials

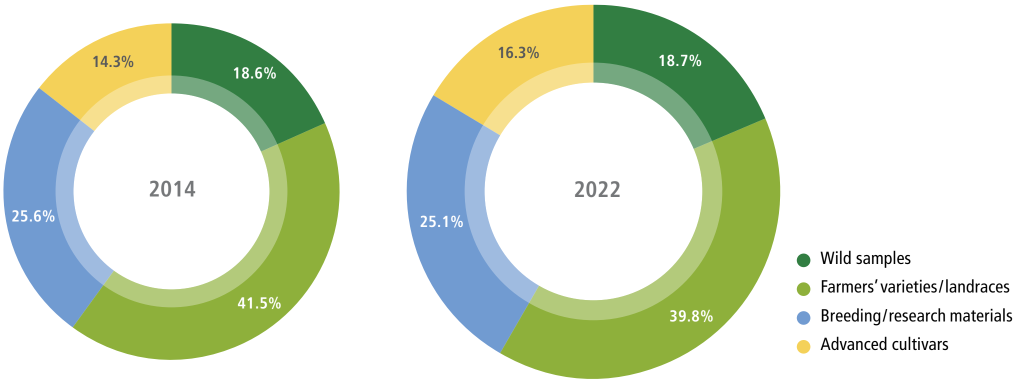
For the purposes of this report, wild PGRFA include CWR, WFP and other wild flora. Accessions classified as wild materials make up 19 percent of all global accessions for which biological status is documented.

FIGURE 3.4
Sources of accessions in genebank collections in 2014 and 2022



Notes: Data cover international, regional and national genebanks except the Nottingham Arabidopsis Stock Centre. The size difference in the charts represents the growth in the numbers of accessions held *ex situ* and documented for this descriptor between 2014 and 2022. *Accessions of farmers' varieties/landraces that have been reported without collecting source information are included in this category. **Accessions of breeding/research materials that have been reported without collecting source information are included in this category.
Source: FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)*. [Cited 19 December 2023]. https://www.fao.org/wiews/en/

FIGURE 3.5
Biological status of samples in *ex situ* collections in 2014 and 2022



Notes: The percentages are based on reported national and regional/international collections totalling 3 187 555 and 3 849 688 accessions in 2014 and 2022, respectively (excludes collections from the Nottingham Arabidopsis Stock Centre and missing values).
Source: FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS).* [Cited 19 December 2023]. https://www.fao.org/wiews/en/

TABLE 3.9
Biological status of samples in *ex situ* collections, by region

Region (No. of countries)		Total accessions*	Biological status (%)			
			Wild samples	Farmers' varieties/ landraces	Breeding/research materials	Advanced/ improved cultivars
National	Northern Africa (5)	114 365	12	41	46	1
	Sub-Saharan Africa (22)	172 904	6	87	6	2
	Northern America (2)	542 482	27	19	26	29
	Latin America and the Caribbean (17)	245 100	14	44	21	20
	Oceania (2)	268 486	31	15	42	12
	Asia (26)	572 209	12	43	37	8
	Europe (36)**	1 059 211	22	32	20	26
Regional genebanks		57 194	13	47	32	8
International genebanks		817 737	15	58	20	7
Grand total		**3 849 688**	**19**	**40**	**25**	**16**

Notes: *With documented biological status. **Collection from the Nottingham Arabidopsis Stock Centre not included.

Crop wild relatives

CWR are estimated to make up 9 percent of total holdings and 76 percent of all wild samples[24] (547 796 accessions) (Table 3.10). CWR holdings include 429 genera and 6 101 species, maintained across 428 genebanks in 104 countries and three regional and 13 international genebanks. The number of CWR accessions conserved *ex situ* increased by 17 percent between 2014 and 2022, and the number of species increased by 8 percent. Eleven countries[25] maintain collections of CWR, which vary between 10 168 and 80 813 accessions each, accounting altogether for 64 percent of all CWR accessions conserved *ex situ* globally. Regional and international genebanks conserve 19 percent of all CWR germplasm; the equivalent figure was 16 percent in 2014. The international centres holding the largest numbers of CWR are ICARDA (almost 32 000 accessions from 384 species), CIAT (~20 000 accessions from 421 species) and ILRI (~11 000 accessions from 5 645 species).

Forages (43 percent of all conserved CWR samples) and cereals (26 percent) are the most represented crop groups.[26] Forages (1 790 species), fruit plants (799 species) and vegetables (668 species) are the groups represented by the largest numbers of species. In terms of the method of conservation, 95 percent of CWR accessions are conserved *ex situ* as seed, 4.6 percent in field collections, 0.6 percent in vitro, 1 percent under cryopreservation and 0.2 percent as DNA.

Geographic origin is reported for 89 percent of all the CWR samples conserved. Of these, 35 percent (171 087) are conserved in the subregion where they were collected (Table 3.10). This proportion varies greatly by region and subregion– highest in Northern America (76 percent), Eastern Europe (74 percent) and Australia and New Zealand (72 percent), and lowest in Melanesia (1 percent), Central Asia (4 percent), Southern Africa (5 percent), South-eastern Asia (7 percent), Western Africa (13 percent) and South America (15 percent). No germplasm from Middle Africa is reported conserved in the subregion, as no *ex situ* facilities are reported. The fact that CWR are mainly conserved outside the subregions where they were collected is probably a consequence of a lack of capacity, including a lack of knowledge of their biology and taxonomy and of technology for using them, a lack of funding and a lack of understanding of their potential value. Where national CWR *ex situ* holdings are relatively small in a given subregion, regional and international centres play an important role in that they conserve a significant proportion of CWR from the subregion, including from countries that lack *ex situ* facilities.

Wild food plants

WFP *ex situ* holdings comprise roughly 46 900 accessions from 802 species (Table 3.11). This estimate is based on reporting by countries and regional/international genebanks on wild samples of species that are known to be harvested for food from the wild. WFP that are used as vegetables account for 39 percent of these accessions, those providing fruit for 38 percent, those providing nuts for 9 percent and those providing herbs and spices for 7 percent. In terms of the method of conservation, 66 percent of the WFP accessions are held as seed, 33 percent in fields, 2.7 percent as DNA, 3.2 percent *in vitro* and 0.8 percent under cryopreservation. Since 2014, the number of WFP accessions held has increased by 39 percent (16 percent in national holdings and 372 percent in regional and international holdings) and the number of species conserved has increased by 6 percent.

The largest *ex situ* holdings of WFP are found in the United States (9 467 accessions, 47 percent of which are native, belonging to 400 species), Brazil (4 197 accessions belonging to 53 species) and the United Kingdom (3 029 accessions belonging to 498 species). Other countries with holdings of more than 1 000 accessions include Mexico,

[24] CWR were identified based on the species and the biological status of the samples. Samples of known CWR species with wild or unreported biological status and samples of cultivated species with wild biological status were included.

[25] Australia, Canada, Germany, India, Israel, Japan, Poland, Russian Federation, Spain, United Kingdom, United States.

[26] See Section 3.4.4.

TABLE 3.10

Number of accessions of crop wild relatives collected (totals by subregion) and conserved *ex situ* (totals by subregion and for regional/international genebanks)

Accessions conserved in	Accessions collected in: Northern Africa	Eastern Africa	Southern Africa	Middle Africa	Western Africa	Northern America	Central America	Caribbean	South America	Central Asia	Eastern Asia	South-eastern Asia	Southern Asia	Western Asia	Northern Europe	Eastern Europe	Southern Europe	Western Europe	Australia and New Zealand	Melanesia	Micronesia	Polynesia	Not specified	Total
Northern Africa	**10 259**	1							1	42	10		67	319	1	13	5						36	**10 754**
Eastern Africa	1	**3 243**	1		5	6			1					3	1		2	11	21				12	**3 307**
Southern Africa			**205**																					**205**
Middle Africa				**0**																				**0**
Western Africa					**734**																			**734**
Northern America	5 083	2 061	779	115	480	**17 690**	3 810	513	6 727	4 293	4 302	204	5 400	32 037	939	4 896	7 438	1 740	1 760	90		9	10 226	**110 592**
Central America		18		12	1		**6 217**	1	6		1							4					17	**6 277**
Caribbean						4	5	**919**	69			73	14					1		8			120	**1 213**
South America						125			**6 009**		1	11	10	2	4	7	34	18	4	9			7 160	**13 394**
Central Asia	4	13		4	2	93	37	6	22	**565**	123	3	89	88	2	36	4	9	15				73	**1 188**
Eastern Asia	155	75	180	3	6	28	34		39		**2 605**	41	199	1 115	14	36	72	15	21	4			16 221	**20 863**
South-eastern Asia												**554**											153	**707**
Southern Asia	2	157	3		8	271	13		3		36	26	**7 730**	568	1		71	89	2				2 271	**11 251**
Western Asia	3	2	3							55	2		31	**30 031**	1	24	10	15					132	**30 309**
Northern Europe	568	1 450	463	155	897	1 229	820	75	1 029	307	873	378	499	6 931	**6 131**	1 866	4 646	3 159	420	6			3 135	**35 037**
Eastern Europe	206	25	29	4	8	840	677	8	1 864	3 959	553	6	664	4 811	704	**34 445**	1 729	1 640	234			2	6 104	**58 512**
Southern Europe	3 81	39	31		14	170	256	2	728	1	51	33	227	1 812	136	360	**25 066**	526	62	5			1 028	**30 928**
Western Europe	1 429	929	114	398	170	291	1 170	23	3 573	818	213	29	510	3 393	895	2 098	3 396	**10 007**	62	4			4 285	**33 807**
Australia and New Zealand	11 572	1 812	1 305	86	244	1 601	2 198	308	4 044	1 337	335	478	2 311	15 339	298	1 248	17 767	1 630	**8 673**	116	4	15	4 180	**76 901**
Melanesia																				**4**				**4**
International/ regional centres	5 086	7 247	1 372	1 003	2 980	908	6 886	366	16 202	1 209	1 715	5 625	5 512	25 701	4 543	1 332	4 963	711	728	238	4	14	7 468	**101 813**
Total accessions	**34 749**	**17 072**	**4 485**	**1 780**	**5 549**	**23 256**	**22 123**	**2 221**	**40 317**	**12 586**	**10 820**	**7 461**	**23 263**	**122 150**	**13 670**	**46 361**	**65 203**	**19 575**	**12 002**	**484**	**8**	**40**	**62 621**	**547 796**

Note: The diagonal in bold face represents accessions collected and conserved in the same subregion.

TABLE 3.11

Number of accessions of wild food plants collected (totals by subregion) and conserved *ex situ* (totals by subregion and for regional/international genebanks)

Accessions conserved in	Accessions collected in: Northern Africa	Eastern Africa	Southern Africa	Middle Africa	Western Africa	Northern America	Central America	Caribbean	South America	Central Asia	Eastern Asia	South-eastern Asia	Southern Asia	Western Asia	Northern Europe	Eastern Europe	Southern Europe	Western Europe	Australia and New Zealand	Melanesia	Not specified	Total
Northern Africa	**701**		1			1								1								**704**
Eastern Africa	18	**524**				18							2	12				2	18		6	**600**
Southern Africa			**75**																			**75**
Middle Africa				**0**																		**0**
Western Africa					**78**																	**78**
Northern America	59	73	153	5	4	**5 618**	116	9	1 132	76	364	37	106	462	75	405	270	136	33	3	1 718	**10 854**
Central America							**1 684**														33	**1 717**
Caribbean							5	**6**	3									1				**15**
South America						59	1		**991**							1	12	2			5 435	**6 501**
Central Asia										**116**					2	1			1		2	**122**
Eastern Asia						1			4		**101**	6		2				1			691	**806**
South-eastern Asia												**90**										**90**
Southern Asia													**1 205**								169	**1 374**
Western Asia						2			3	20	1			**1 573**	3	1	1	6			8	**1 618**
Northern Europe	38	275	159	6	124	148	115	7	75	37	76	39	50	755	**809**	77	206	129	62	1	222	**3 410**
Eastern Europe	1	4	5		1	57	2	1	70	193	32		4	100	45	**1 255**	102	168			729	**2 769**
Southern Europe	24		5		5	3	8		204			2	7	39	7	4	**1 150**	18			155	**1 631**
Western Europe	9	2	2		1	19	13	12	90	183	27	5	32	401	45	238	312	**923**			770	**3 084**
Australia and New Zealand	108	3	1			4	1		78				10	71		1	109	20	**613**		172	**1 191**
Melanesia																				**0**		**0**
International/regional centres	299	6 263	301	1 098	646	45	122	13	628	3	62	286	54	165	140	12	43	16	5	25	90	**10 316**
Total accessions	**1 257**	**7 144**	**702**	**1 109**	**859**	**5 975**	**2 067**	**48**	**3 278**	**628**	**663**	**465**	**1 470**	**3 581**	**1 126**	**1 995**	**2 205**	**1 422**	**732**	**29**	**10 200**	**46 955**

Note: The diagonal in bold face represents accessions collected and conserved in the same subregion.

Germany, Chile, Canada, India, the Kingdom of the Netherlands and Australia. Regional and international centres conserve 10 097 WFP accessions from 113 species. ICRAF, with over 7 850 accessions from 13 species, holds the largest collection of WFP.

On average, 48 percent (17 512) of the WFP accessions with known geographic origins are conserved in the subregion where they were collected. This percentage varies significantly among subregions – highest in Northern America (94 percent), Australia and New Zealand (84 percent), Southern Asia (82 percent), Central America (81 percent) and Northern Europe (72 percent) and lowest in Eastern Africa (7 percent), Western Africa (9 percent), Southern Africa (11 percent), the Caribbean (13 percent) and Eastern Asia (15 percent). Where national WFP *ex situ* holdings are relatively small in a given subregion, regional and international centres conserve a significant proportion of WFP from the subregion, including from those countries that lack *ex situ* facilities. A lack of capacity, interest and funding in the areas where these resources were collected, together in some cases with their relative abundance in the wild, appear to be the reasons for their conservation outside their areas of origin.

Several sub-Saharan African countries, namely Ghana, the Niger, South Africa, Togo, Zambia and Zimbabwe, stress the importance of WFP and the need to collect and conserve them. Fifteen of the 91 countries that provided reports for *The State of the World's Biodiversity for Food and Agriculture* (FAO, 2019b) reported that regular use of wild foods by their populations is widespread. Two studies of wild foods from forests in Zambia revealed that rural households collected about 31 kg of fruits, vegetables, mushrooms and tubers in 2015 and that 97 percent of households in the Mwekera area collected wild fruits (Steel *et al*., 2022). There are a number of WFP species that are conserved in one or only in a few genebanks globally.

Other wild flora

Other wild flora conserved *ex situ* consists of germplasm lacking a defined use in food and agriculture, as well as pasture species, medicinal plants, ornamentals, plants harvested from the wild for a specific compound or material, and weeds. *Ex situ* holdings falling into this category comprise over 38 950 species and 194 740 accessions. Many of these species are being studied for their ecological roles, for example in erosion control, nutrient recycling, land restoration and phytoremediation. The within-species diversity of this category is poorly represented in *ex situ* collections, with fewer than six accessions conserved for 87 percent of species. Between 2014 and 2022, the number of species of other wild flora conserved *ex situ* increased by 17 percent and the number of accessions increased by 26 percent.

Farmers' varieties/landraces

FV/LR are an important category of germplasm, as they are typically adapted to the prevailing ecological conditions where they are cultivated, which is mostly in traditional production systems (FAO, 2019c). These PGRFA have traditionally been given the highest priority by collectors and genebanks. The number of accessions of FV/LR are summarized by region in Table 3.9. Overall, 29 percent of all accessions conserved *ex situ* are FV/LR. This increases to 40 percent if only accessions with known biological status are considered (Figure 3.5). The region whose collections contain the highest proportion of FV/LR is sub-Saharan Africa, where this category accounts for 87 percent of all accessions conserved and characterized for biological status. Figures are also relatively high in Latin America and the Caribbean (44 percent), Asia (43 percent) and Northern Africa (41 percent).

FV/LR make up 69 percent of all accessions with known biological status among pseudo-cereals, 62 percent among pulses, 56 percent among roots and tubers, 52 percent among vegetables, and between 44 and 40 percent among fruit plants, oil plants, herbs and spices, stimulants, nuts, and cereals. They make up 74 percent of pseudo-cereal accessions conserved in Asia, 83 percent in sub-Saharan Africa and 97 percent in Latin America and the Caribbean. In all regions other than Oceania, they represent over 50 percent of all holdings of pulses, the highest percentages being in Northern Africa (88 percent) and sub-Saharan Africa (84 percent). FV/LR represent 64 percent of root and tuber accessions across Latin America and the Caribbean, 93 percent in sub-Saharan Africa and 99 percent in Oceania. Among vegetables, they represent between 60 percent of the total in Latin America and the Caribbean, 67 percent in Northern Africa and 89 percent in sub-Saharan Africa. They represent 44 percent of the total for fruit plants in Asia, 45 percent in Latin America and the Caribbean, 52 percent in Europe, 86 percent in Oceania and 96 percent in Northern Africa. There are also high percentages of FV/LR among cereals (56 percent), stimulants (64 percent), pulses (75 percent), roots and tubers (76 percent), vegetables (79 percent), oil plants (89 percent) and pseudo-cereals (95 percent) in regional and international genebanks.

Several countries, including Armenia, Malaysia and Mexico, note that there are gaps in the coverage of FV/LR in their collections.

Breeding/research materials

Breeding/research materials represent 18 percent of all accessions conserved worldwide[27] and a quarter of those that are characterized for this descriptor. They also account for about one-third of all conserved accessions of cereals (35 percent), sugar crops (37 percent) and fibre plants (30 percent) characterized for this descriptor and about one-quarter in the case of oil plants (27 percent) and stimulants (26 percent). Among regions, they range from 6 percent of the conserved accessions characterized for this descriptor in sub-Saharan Africa to 42 percent in Oceania and 46 percent in Northern Africa.

Advanced/improved cultivars

Advanced/improved cultivars represent 12 percent of all accessions conserved worldwide[28] and 16 percent of those that are characterized for this descriptor. The proportion of advanced/improved cultivars among the characterized holdings maintained within regions ranges from 1 percent in Northern Africa to 29 percent in Northern America. Ornamentals, fibre plants, sugar crops, fruit plants, oil plants and vegetables are the use groups with the highest proportions of advanced/improved cultivars among all accessions characterized for this descriptor, ranging from 41 percent to 20 percent.

Unknown

At the global level, 28 percent of accessions have unknown biological status. Latin America and the Caribbean has the highest percentage of accessions with unknown biological status, about 49 percent, followed by Asia with 45 percent and Europe with 29 percent. Although these figures are quite high, the proportion of accessions with unknown status declined between 2014 (34 percent) and 2022 (28 percent) (Table 3.13).

3.4.4 Germplasm accessions stored in genebanks categorized by crop group

The numbers of accessions conserved *ex situ* in national, regional and international holdings are presented by crop group in Table 3.12. Unsurprisingly, the groups with the largest numbers of accessions conserved are the major food crops. The one exception is the category "other," which includes the large collection at the Nottingham Arabidopsis Stock Centre.

Forages, medicinal plants, ornamentals and material plants are the groups with the highest percentages of wild samples, both in 2014 and in 2022 (Table 3.13). Fibre plants and pulses have the lowest percentages of wild samples,

[27] The collection at the Nottingham Arabidopsis Stock Centre is excluded.

[28] The collection at the Nottingham Arabidopsis Stock Centre is excluded.

followed by cereals and oil plants. Landraces are most prominent among roots and tubers, followed by pulses and pseudo-cereals. They are less common among material plants, forages and ornamentals. Sugar crops and cereals have the highest proportions of breeding materials, while ornamentals have the highest proportion of advanced cultivars. The breeding/research category is common in the "other" group, a consequence of the large proportion of *Arabidopsis* within this group.

Common methods of conservation and types of plant material conserved

PGRFA consist of different types of germplasm that require different conservation approaches. The most common conservation approaches and types of plant material conserved are summarized in Box 3.2. It should be noted that more than one storage method and type of plant material can be utilized for a given species (Engels and Ebert, 2021). It is not uncommon for species to be maintained in a field genebank and also conserved *in vitro* culture and/or cryopreserved. Similarly, those conserved through more conventional methods may also be stored as pollen or DNA.

The total numbers of accessions kept under each type of storage in national genebanks and in regional and international genebanks are presented in Tables 3.14 and 3.15, respectively. The numbers of accessions kept under each type of storage by region and subregion is shown in Table 3.16 and for specific international and regional genebanks in Table 3.17.

TABLE 3.12

Number of accessions conserved *ex situ* for different crop groups and their distribution across national, regional and international holdings

Crop group	Accessions	Accessions (%)		
		National	Regional	International
Cereals	2 474 340	77	1	22
Pulses	709 756	73	1	26
Forages	502 832	85	1	14
Vegetables	397 074	89	2	9
Fruit plants	276 281	96	0.5	3.6
Oil plants	210 800	90	0.4	9.3
Fibre plants	127 665	99	0.3	0.4
Roots and tubers	115 625	71	2.3	27
Ornamentals	58 140	99	0.3	0.3
Herbs and spices	55 844	97	0.5	2.2
Medicinal plants	55 038	95	2	3
Pseudo-cereals	41 985	92	1	7
Material plants	41 797	94	0.1	5.4
Stimulants	41 659	92	8	0
Sugar crops	18 394	100	0	0
Nuts	17 067	97	0	3
Others*	797 319	100	0	0
Total	5 941 616	84	1	15

Note: *Others include *Arabidopsis* plus wild flora.

TABLE 3.13

Number of accessions conserved *ex situ* for different crop groups and biological types in 2014 and 2022

Crop group	2022						2014					
	No. of accessions	Wild materials* (%)	Landraces (%)	Breeding materials (%)	Advanced cultivars (%)	Others** (%)	No. of accessions	Wild materials* (%)	Landraces (%)	Breeding materials (%)	Advanced cultivars (%)	Others** (%)
Cereals	2 474 340	6	31	27	13	23	2 202 530	6	32	25	9	28
Pulses	709 756	5	43	14	8	30	647 926	4	41	12	7	36
Forages	502 832	55	5	7	7	26	474 867	46	6	6	6	37
Vegetables	397 074	9	36	9	14	31	350 727	9	28	9	13	41
Fruit plants	276 281	12	32	11	18	28	249 938	8	31	12	19	30
Oil plants	210 800	6	27	17	13	38	194 395	5	20	15	11	49
Fibre plants	127 665	5	16	16	16	48	119 343	4	14	16	17	49
Roots and tubers	115 625	16	49	13	10	12	107 017	15	43	17	10	15
Ornamentals	58 140	34	8	6	34	18	51 178	36	8	6	17	34
Herbs and spices	55 844	20	26	7	7	41	49 072	18	25	7	7	44
Medicinal plants	55 038	53	13	5	3	27	44 325	50	10	5	4	31
Pseudo-cereals	41 985	7	40	4	7	42	35 744	7	35	9	3	46
Material plants	41 797	27	9	8	2	56	35 902	24	8	9	1	58
Stimulants	41 659	10	31	19	13	27	39 355	11	26	18	11	34
Sugar crops	18 394	14	15	32	25	14	19 821	14	14	28	23	21
Nuts	17 067	22	28	7	11	32	16 404	17	30	9	11	34
Other***	797 319	12	0	51	0	37	745 807	10	0	52	0	38
Total/overall mean	5 941 616	12	26	23	11	28	5 384 351	11	25	22	9	34

Notes: *This category includes weedy accessions (0.2 percent in 2014 and 0.2 percent in 2022). **This category includes unclassified accessions and two genetically modified accessions in 2014 and 27 in 2022. ***Under this group 86 percent of total accessions in 2022 and 88 percent in 2014 were collections at the Nottingham Arabidopsis Stock Centre.

TABLE 3.14

Storage types used for *ex situ* conservation in national genebanks

Storage type	Genera (No.)	Species (No.)	Accessions (No.)	Accessions (%)	Countries (No.)	Genebanks (No.)
Seed collection	6 728	45 224	3 779 929	76	108	438
Field collection	2 149	8 974	397 705	8	84	587
In vitro collection	152	633	32 145	1	37	81
Cryopreserved collection*	1 611	4 519	694 298	14	13	27
DNA collection	755	1 527	6 109	0.1	8	11
Unspecified**	2 301	9 840	110 313	2	34	189
Total	7 281	50 990	4 976 565		116	852

Notes: **Arabidopsis* accessions stored under cryopreservation account for 682 556 of the accessions in this category.
**Countries and genebanks are counted when storage-type information is unspecified for at least one accession even though the accession is reportedly under medium- or long-term conservation. These data do not include the internal backup collections at the USDA National Laboratory for Genetic Resource Preservation in Fort Collins, United States.

Box 3.2

Common methods of conservation and types of plant material conserved

- **Seed genebanks:** Species that produce orthodox seeds (seeds that can be dried and stored at low temperature and humidity) are easily conserved in seed genebanks. Orthodox seeds are typically stored in genebanks after having been dried and packed in airtight containers. In medium-term storage, seeds are maintained under refrigeration at 5–10 °C and a relative humidity of 15±3 percent (FAO, 2014; 2024). Long-term storage is generally at -20 °C, with seeds stored in hermetically sealed containers.
- **Field genebanks**: Species that produce recalcitrant seed (seeds that cannot survive drying and storage at low temperature) or seeds with intermediate storage characteristics, those that are vegetatively propagated and those that are long-lived or perennials are commonly conserved as whole plants in field genebanks. Such species comprise about 8–10 percent of flowering plant species. They can also be conserved through *in vitro* culture and/or cryopreservation.
- ***In vitro* culture:** As an alternative to the conservation of live plants in field genebanks, germplasm can be conserved using tissue culture. Under this approach, tissue is taken from plants to form explants that will grow on a substrate under optimal temperature, light and relative humidity conditions and can be conserved for short- or medium-term durations, especially under slow-growth conditions for which the frequency of subculturing is low. The development of new (or adaptation of existing) *in vitro* culture protocols for each species (and sometimes at the varietal level or even for individual genotypes) is a fundamental aspect of optimizing their storage.
- **Cryopreservation:** This method involves the long-term preservation of various plant parts (tissue, meristem, pollen or dormant buds) in liquid nitrogen. As in the case of *in vitro* culture, methodologies are often specific to the species, variety or even genotype. Cryopreservation is often used as a means of safety backup for germplasm conserved in field genebanks or under *in vitro* culture. A useful review of this type of germplasm conservation can be found in Reed (2017).
- **Storage of pollen:** Pollen can be stored at -80 °C or cryopreserved. It stays viable and functional for up to ten years. As most species produce storable pollen, this method allows for the storage of vast numbers of samples using relatively little space and at lower costs than other methods. Pollen, however, only provides half the genome and must be used to fertilize a female egg cell to obtain a new plant. For some crops (e.g. coconuts), pollen provides the only safe way of exchanging genetic diversity and is relatively easy to ship to specialized recipients without spreading diseases.
- **Conservation of DNA**: DNA extracted from plants is relatively easy to handle and store. With the increasing importance of molecular techniques applied to germplasm materials, the storage of DNA samples from plants is becoming increasingly common. DNA can be maintained at -20 °C in short- and medium-term storage (up to ten years) and at -70 °C in liquid nitrogen for much longer periods (comparable to long-term seed storage)

Sources: FAO. 2014. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rev. ed. Rome. https://www.fao.org/3/i3704e/i3704e.pdf; FAO. 2024. *WIEWS Reporting Tool for the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture*. [Cited 7 July 2024]. https://www.fao.org/pgrfa/; Reed, B.M. 2017. Reed, B.M. 2017. Plant cryopreservation: a continuing requirement for food and ecosystem security. *In Vitro Cellular & Developmental Biology* – Plant. 53(4), 285–288. https://doi.org/10.1007/s11627-017-9851-4

TABLE 3.15

Storage types used for *ex situ* conservation in regional and international genebanks

Storage type	Genera (No.)	Species (No.)	Accessions (No.)	Accessions (%)	Genebanks (No.)
Seed collection	777	3 518	920 178	95	15
Field collection	210	357	30 214	3	8
In vitro collection	26	122	27 419	3	6
Cryopreserved collection	3	26	1 281	0.1	2
DNA collection	0	0	0	0	0
Unspecified	45	91	4 823	0.5	3
Total	928	3 864	965 051		17

TABLE 3.16

Number of accessions held under different types of *ex situ* storage, by region and subregion

Regions and subregions (number of countries)	Seed collection	Field collection	*In vitro* collection	Cryo collection	DNA collection	Number of genebanks
Northern Africa (5)	128 725	1 663	0	0	0	5
Northern Africa (5)	128 725	1 663	0	0	0	5
Sub-Saharan Africa (23)	202 451	12 332	2 112	0	0	54
Eastern Africa (9)	159 467	7 523	0	0	0	25
Southern Africa (5)	15 933	464	0	0	0	7
Western Africa (9)	27 051	4 345	2 112	0	0	22
Northern America (2)	622 921	27 979	7 405	0	0	30
Northern America (2)	622 921	27 979	7 405	0	0	30
Latin America and the Caribbean (19)	401 580	72 223	11 122	27	2 413	203
Central America (7)	72 828	12 347	915	27	0	90
Caribbean (2)	11 008	9 676	259	0	287	19
South America (10)	317 744	50 200	9 948	0	2 126	94
Oceania (3)	333 532	2 797	6	0	0	11
Melanesia (1)	190	2 797	6	0	0	8
Australia and New Zealand (2)	333 342	0	0	0	0	3
Asia (27)	976 138	52 000	830	2 180	982	104
Central Asia (3)	69 914	5 668	0	0	0	10
Eastern Asia (2)	216 509	30 415	0	1 444	0	2
South-eastern Asia (6)	87 176	9 073	290	8	64	38
Southern Asia (7)	516 900	4 276	539	728	0	31
Western Asia (9)	85 639	2 568	1	0	918	23
Europe (37)	1 114 582	228 711	10 670	692 091	2 714	445
Northern Europe (9)	165 399	11 141	1 107	689 053	2 625	63
Eastern Europe (10)	573 720	68 093	4 734	455	89	136
Southern Europe (12)	161 756	70 138	403	1	0	125
Western Europe (6)	213 707	79 339	4 426	2 582	0	121
Total (116)	3 777 929	397 705	32 145	694 298	6 109	852

TABLE 3.17
Number of accessions held under different types of *ex situ* storage in international and regional genebanks

Regions and subregions (number of countries)	Seed collection	Field collection	*In vitro* collection	Cryo collection	Total
International genebanks					
AfricaRice	21 815	0	0	0	21 815
Bioversity ITC	0	0	1 693	1 235	1 693
CIAT	60 593	0	5 963	0	66 556
CIMMYT	213 600	0	0	0	213 600
CIP	9 896	6 849	11 285	0	16 364
ICARDA	152 286	0	0	0	152 286
ICBA	15 142	0	0	0	15 142
ICRAF	6 384	8 848	0	0	15 232
ICRISAT	146 250	0	0	0	146 534
IITA	28 249	9 508	5 856	46	37 757
ILRI	18 501	138	0	0	18 639
IRRI	132 602	2	0	0	132 604
WorldVeg	64 238	0	0	0	68 727
Total	869 556	25 345	24 797	1 281	906 949
Regional genebanks					
CATIE	6 122	4 828	0	0	10 950
CePaCT	0	5	2 520	0	2 520
NordGen	33 174	36	102	0	33 306
SPGRC	11 326	0	0	0	11 326
Total	50 622	4 869	2 622	0	58 102

TABLE 3.18
Types of storage expressed as percentages of the number of accessions conserved *ex situ* for different crop groups

Crop group	Accessions	Storage types (%)					
		Seed	Field	*In vitro*	Cryo.	DNA	Unknown
Cereals	2 474 340	99	0.3	0	0	0	1
Pulses	709 756	98	0.4	0	0	0	1
Forages	502 832	97	1	0	0.1	0.1	2
Vegetables	397 074	94	3	0.1	0.2	0.2	4
Fruit plants	276 281	11	81	4	1	0.7	6
Oil plants	210 800	96	3	0	0	0.1	1
Fibre plants	127 665	94	4	0	0	0	2
Roots and tubers	115 625	32	52	41	2	0.4	1
Ornamentals	58 140	41	53	0.5	0.8	0.1	7
Herbs and spices	55 844	82	12	2	0.6	0.1	5
Medicinal plants	55 038	84	8	0.8	1	0.5	8
Pseudo-cereals	41 985	95	1	0	0.1	0	5
Material plants	41 797	75	16	0.1	2	0.2	10
Stimulants	41 659	38	61	0.2	0	0.7	2
Sugar crops	18 394	44	51	0.1	0.1	0	7
Nuts	17 067	17	69	0.6	0.1	0	15
Others	797 319	11	1	0	86	0.1	2

Seed genebanks and their status

Seed storage is by far the most frequently used *ex situ* conservation method, with more than 4.7 million accessions (79 percent of total global germplasm holdings) maintained in 438 national genebanks in 108 countries and 15 regional/ international genebanks. Of these accessions, 40 percent are maintained in medium-term storage, 78 percent in long-term storage and 17 percent in both. Countries with seed holdings of more than 100 000 accessions include, in decreasing order, the United States, India, Australia, the Russian Federation, Japan, Brazil, the United Kingdom and the United States, Germany and Canada. The regions maintaining the largest numbers of accessions as seed are Europe (195 genebanks in 34 countries), Latin America and the Caribbean (113 genebanks in 18 countries) Asia (56 genebanks in 25 countries) and Northern America (25 genebanks in two countries). More than 900 000 accessions (16 percent of the global total) are conserved as seed in three regional and 12 international genebanks (Table 3.15). CIMMYT, ICARDA, ICRISAT and IRRI each have more than 100 000 accessions in their seed collections (Table 3.17).

Between 94 percent and 99 percent of all *ex situ* holdings of cereals, pulses, forages, vegetables, oil plants, fibre plants and pseudo-cereals are conserved as seed. Fruit plants, nuts and roots and tubers are among the crop groups less represented in seed banks, which account for between 11 percent and 32 percent of holdings in each of these groups (Table 3.18).

Field genebanks and their status

About 428 000 accessions, over 7 percent of germplasm maintained *ex situ* globally, are held in 587 field genebanks in 84 countries and eight regional or international centres (Table 3.14 and Table 3.15). These collections represent more than 9 091 species. About 40 108 field genebank accessions are also maintained as seed, *in vitro*, as DNA and/or in cryopreserved form.

Portugal, Germany and Japan lead a list of 13 countries[29] holding more than 10 400 accessions in field collections. Among these, Mexico operates a national network of 47 field genebanks, Spain has 34 and Ukraine, Romania, Italy and Brazil all have more than 20. In Cuba, 46 percent of the *ex situ* holdings are maintained in 12 field genebanks, while in Papua New Guinea 87 percent of the *ex situ* holdings are conserved in eight field genebanks. A significant proportion of *ex situ* conservation efforts in Nordic countries focus on field collections, as their seed collections are conserved in the regional genebank. Europe, Latin America and the Caribbean, Asia and Northern America are the regions with the largest numbers of accessions maintained in field genebanks (Table 3.16).

Among the 10 950 accessions conserved at the CATIE regional genebank in Costa Rica, 44 percent are maintained in field collections (Table 3.17). These collections include coffee (1 990 accessions), cocoa (1 245 accessions), peach palm (614 accessions) and other fruit trees. The international genebanks conserve 25 345 vegetatively propagated accessions in field collections. These make up 3 percent of all the accessions maintained by the international genebanks and 0.4 percent of the global total. The international genebanks with the largest field collections include IITA, ICRAF and CIP.

Fruit plants (81 percent of their total *ex situ* holdings), nuts (69 percent), stimulant plants (61 percent), roots and tubers (52 percent) and ornamentals (53 percent) are the plant groups most represented in field genebanks (Table 3.18). More than 90 percent of grape, *Rhododendron*, coffee, cocoa, tea, *Uapaca*, olive tree, *Oxalis*, mango, *Euterpe*, avocado, *Ullucus*, cashew and rubber tree holdings are conserved in field genebanks. Crops for which more than 80 percent of holdings are conserved in field genebanks

[29] Portugal, Germany, Japan, United States, Switzerland, Brazil, Romania, Ukraine, France, Spain, Italy, Mexico, Belarus. Countries are listed in descending order.

include *Malus, Prunus* and *Pyrus*, sugar cane, yam, walnut and hazelnut.

In vitro *collections and their status*

Only 1 percent of accessions worldwide are maintained through *in vitro* culture, including 32 145 accessions in national genebanks and 27 419 in regional and international genebanks (Table 3.14 and Table 3.15). About 60 percent of those accessions are also maintained as seed in cold storage, plants in field genebanks and/or in cryopreserved form. Thirty-seven countries operate *in vitro* storage facilities and maintain germplasm *in vitro*.[30] A total of 698 species are conserved *in vitro*.

With the exception of Northern Africa, all regions reported germplasm holdings in vitro (Table 3.16). Europe, Northern America, and Latin America and the Caribbean each maintain more than 7 400 accessions. Four CGIAR genebanks (CIAT, CIP, IITA and the Bioversity International Musa Germplasm Transit Centre [ITC]) maintain a combined total of 24 797 accessions *in vitro* (Table 3.17). CePaCT maintains 2 520 accessions of 27 taxa *in vitro*, and SPGRC maintains 102 accessions.

In vitro conservation is heavily used in important collections of roots and tubers (Table 3.18) such as cassava (66 percent of all accessions), *Ullucus* (48 percent), yams (44 percent), *Ipomoea* (39 percent), *Colocasia* (34 percent), potato (33 percent), *Oxalis* (32 percent) and *Tropaeolum* (23 percent) as well as in collections of fruit plants such as *Musa* (43 percent) and strawberries (36 percent). Since the publication of the SoW2, the amount of germplasm stored *in vitro* has increased by 10 percent overall. There have been significant increases in *in vitro* collections relative to 2009 for yams (25 percent increase at CePaCT; 31 percent at IITA), *Musa* (32 percent at ITC; 67 percent at IITA), potatoes (32 percent in Belarus; 17 percent in Czechia; 10 percent in Ecuador; 9 percent in the United States; 8 percent at CIP), sweet potatoes (6 percent at CePaCT; 11 percent at CIP), cassava (15 percent at Embrapa Cassava and Fruits in Brazil; 11 percent at IITA). In Malaysia, the Malaysian Agricultural Research and Development Institute established an *in vitro* collection of Musa, and in Sri Lanka the *in vitro* yam collection at the Plant Genetic Resources Centre has almost tripled in size since 2009.

Cryopreserved collections and their status

If the *Arabidopsis* model plant research collection managed by the Nottingham Arabidopsis Stock Centre is included, cryopreservation is the second most widely used *ex situ* conservation method by national genebanks (14 percent) (Table 3.14). If the Arabidopsis collection is excluded, the relative significance of cryopreservation is more modest (0.3 percent).[31] Nonetheless, the number of accessions cryopreserved in national and international genebanks has increased by 56 percent to 13 037 since 2009, and the number of genera cryopreserved has increased by 65 percent to 1 612. The number of species cryopreserved has doubled, reaching 4 540. This trend is expected to continue in the short term as capacity improves and needs surge, particularly the need to conserve wild species, including edible fruit plants. Thirteen countries report that they store cryopreserved germplasm.[32] Cryopreserved accessions are also maintained as seed in cold storage, as plants in field genebanks and/or via *in vitro* culture. *Solanum, Musa, Morus, Allium, Fragaria* and *Prunus* are the genera most represented in cryopreserved collections. The Bioversity ITC genebank reports that it maintains 1 235 *Musa* accessions using cryopreservation (Table 3.17), a 17 percent increase since 2009.

[30] Argentina, Belarus, Bolivia (Plurinational State of), Brazil, Bulgaria, Canada, Colombia, Costa Rica, Cuba, Czechia, Ecuador, Estonia, Finland, France, Ghana, Germany, Guyana, India, Ireland, Italy, Malaysia, Mexico, Norway, Panama, Papua New Guinea, Philippines, Poland, Romania, Slovenia, Spain, Sri Lanka, Switzerland, Trinidad and Tobago, and the United States.

[31] These data do not include the 49 200 accessions maintained as internal backup at the USDA National Laboratory for Genetic Resource Preservation in Fort Collins, Colorado, United States.

[32] Czechia, Estonia, Finland, Germany, India, Italy, Japan, Lithuania, Nicaragua, Norway, Philippines, Poland, United Kingdom.

DNA collections

A total of 6 109 accessions maintained in 11 national genebanks in eight countries[33] have associated DNA samples stored (0.1 percent of all global accessions) (Table 3.14). While DNA sample collections are increasing within countries, they are often managed by specialized molecular research teams and may not have been reflected in the annual genebank reports for the SDG indicator.

Unspecified

The storage type of 115 129 accessions held in genebanks (2 percent of national holdings and 0.5 percent of regional and international holdings) is unspecified, although they are reported under SDG Indicator 2.5.1.a, which relates to germplasm in collections under medium- or long-term storage.

3.4.5 Redundancy within and between collections and the uniqueness of germplasm accessions

Redundancy within and among collections has remained poorly addressed and documented overall. However, there has been some progress on unwanted duplication within collections thanks to continued rationalization efforts at the country level and in international genebanks. These efforts have been facilitated by reductions in the cost of new molecular tools and information technologies, and by progress in their application. The wide adoption of germplasm documentation standards and advanced genebank data management systems, including Genetic Resource Information Network – Global (GRIN-Global), has increased data comparability and allowed more frequent publication of national inventory data through web portals such as the European Search Catalogue for Plant Genetic Resources (EURISCO) and Genesys. Furthermore, the introduction of the indicators on *ex situ* collections for monitoring the implementation of the GPA2, and later SDG Indicator 2.5.1.a,[34] has helped to mainstream annual reporting on germplasm holdings and to reduce data redundancy for the global assessment of SDG Target 2.5 by focusing on base *ex situ* collections.

The narrative reports from countries provide some observations on redundancy within and among collections. These included mentions of the identification of unwanted duplicates through management of field collections (Portugal), the application of DNA analysis (Finland, Switzerland) and the use of GRIN-Global (Chile). In 2010 and 2011, rationalization of the genebank collection of the Kingdom of the Netherlands resulted in the reduction of its barley, wheat and oat collections thanks to a collaboration with the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) collection in Germany and the USDA collections in the United States of America.

A rough global estimate of the uniqueness of national and international germplasm collections, which is calculated by expressing the size of the largest genebank collection for each conserved species as a proportion of the total holdings for the respective species,[35] stands at 35 percent or about 2 106 833 distinct accessions in 2022. Applying this methodology to the 2009 WIEWS *ex situ* dataset gave a result of 24 percent or 1 375 174 distinct accessions, which is slightly below the 25–30 percent range reported in the SoW2. The significant increase in the estimate of uniqueness in global germplasm holdings is probably caused by several factors, including rationalization efforts made at the national level to increase efficiency and the more focused coverage of SDG Indicator 2.5.1.a, which excludes redundant PGRFA in active collections. The methodology used for this estimate may also be a factor, as it benefits from the improved taxonomic characterization of the germplasm at genebanks and the overall higher quality of data reported.

[33] Belarus, Brazil, Cuba, Czechia, Ecuador, Malaysia, Qatar, United Kingdom.

[34] Further information at https://www.fao.org/sustainable-development-goals/indicators/251a/en/.

[35] The methodology for this estimation is rather rough in that it is based on the assumption that the largest *ex situ* collection of a particular crop includes all unique accessions of that crop conserved globally. A more accurate methodology for estimating the degree of uniqueness was proposed by van Hintum (2000).

As of September 2022, 34 percent of the 1 395 540 accessions recorded in EURISCO were identified as unique accessions (excluding the *Arabidopsis* collection). These data refer to germplasm maintained by 43 European countries that are part of the European Cooperative Programme for Plant Genetic Resources (ECPGR) network (Personal communication: Stephan Weise). Fourteen countries have over 75 percent of the accessions in their national inventories recorded as unique in EURISCO.

A number of species are conserved in one or only a few genebanks globally. Like the above-described issue of unwanted redundancies, this situation is a concern. Low representation in collections, combined with limited or non-existent safety duplication, may imperil the long-term conservation of the respective PGRFA and consequently reduce options for their sustainable use. Some of these species are also classified by IUCN as at risk in their endemic areas (IUCN, 2022). Appendix 3 presents a subset of these species. Each of the 299 species listed[36] has 95 percent or more of its total global holdings (which range between 20 and 3 733 accessions) conserved in only one genebank and less than 50 percent of its accessions safety duplicated. Among these 299 species collections, 80 percent are not safety duplicated (the remaining 59 collections have an average safety duplication level of 20 percent). These species need to be targeted for safety duplication (see Section 3.5), especially those that are not widespread in their natural habitats and are at greater risk of genetic erosion. As many of these species are difficult to conserve (produce recalcitrant seeds or are vegetatively propagated), options for maintaining them under cryopreservation should be considered. Collaboration both within and outside the country where the collections are held, for example with universities or regional and international research institutes should also be explored. An extract of Appendix 3 is presented in Table 3.19.

Sixty-five genebanks conserve these unique collections (a total of 42 684 accessions), 62 are located in 28 countries and three in international centres.[37] Sixty-seven of the species are CWR, 58 are harvested from the wild and used locally as food (WFP), 37 are fruit plant species (10 783 accessions in 19 genebanks), 11 are nut plants (6 283 accessions in eight genebanks), 10 are roots and tubers (1 239 accessions in seven genebanks), 14 are vegetables (834 accessions in 11 genebanks), six are pulses (883 accessions in two genebanks), three are cereal CWR (858 accessions), three are oil plant species (691 accessions), ten are stimulant plants (861 accessions), seven are herbs and spices (300 accessions), and one is an endangered pseudo-cereal, *Cycas micronesica* (23 accessions) held at the USDA Subtropical Horticultural Research Unit, National Germplasm Repository in Miami.

Complementarity between *in situ* and *ex situ* conservation

The natural habitats of CWR, WFP and wild flora with potential value for food and agriculture are the largest reservoirs of genetic diversity for these species. *In situ* conservation is, therefore, an irreplaceable means of safeguarding this diversity and enabling further adaptation. However, given the vulnerability of many such natural habitats, there is also a need to conserve this diversity *ex situ*, in genebanks. Complementary *ex situ* conservation also enhances opportunities for in-depth research into these resources and ultimately for their use.

The genetic diversity of many species found in the wild is threatened by many factors, including climate change. As reflected in countries' collecting efforts (see Section 3.3.1), genebank collections are increasingly safeguarding many vulnerable species. *Ex situ* holdings from 55 countries, two regional and 12 international centres conserve almost 22 000 accessions belonging to 2 103 species collected from the wild that are listed in the IUCN

[36] Excludes synthetic interspecific hybrids, intergeneric hybrids and graft chimaera.

[37] CIAT, ICRAF and IITA.

TABLE 3.19

Selected examples of species conserved in only one or only a few collections

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Min. genebank collection size (accessions)	Max. genebank collection size (accessions)	Max. genebank collection size (%)	Safety duplication % of the max. genebank collection	Holding institute WIEWS code	Holding institute acronym
Fruit plants	*Uapaca kirkiana*		Y	Least Concern	2 927	1	2 927	2 927	100	0	KEN056	ICRAF
Fruit plants	*Euterpe oleracea*				1 831	5	1	1823	99.6	2	BRA018	CPATU
Fruit plants	*Ugni molinae*		Y		123	2	1	122	99.2	0	CHL150	INIA Carillanca
Fruit plants	*Annona macroprophyllata*	Y		Least Concern	117	6	1	112	95.7	0	MEX178	IT-Altamirano
Fruit plants	*Lucuma bifera*		Y	Least Concern	100	1	100	100	100	0	PER041	INIA-EEA.CAN
Fruit plants	*Curculigo latifolia*		Y		45	1	45	45	100	0	MYS125	UPM
Nuts	*Carya illinoinensis*			Least Concern	3 733	10	1	3 615	96.8	0	USA133	BRW
Nuts	*Acrocomia aculeata*	Y	Y	Least Concern	1 526	6	1	1 488	97.5	0	BRA034	CPAC
Nuts	*Juglans neotropica*	Y	Y	Endangered	23	2	1	22	95.7	0	ECU212	JBQ
Pulses	*Vigna minima*	Y	Y		558	7	1	547	98	0	JPN183	NARO
Pulses	*Vigna reflexopilosa*	Y			122	4	1	119	97.5	0	JPN183	NARO
Roots and tubers	*Ensete ventricosum*			Least Concern	310	6	1	303	97.7	0	ETH085	EBI
Roots and tubers	*Manihot peruviana*	Y			91	1	91	91	100	0	COL003	CIAT
Roots and tubers	*Dioscorea sambiranensis*	Y	Y	Near Threatened	33	1	33	33	100	0	GBR004	RBG
Roots and tubers	*Alocasia odora*			Least Concern	26	1	26	26	100	0	VNM049	PRC
Vegetables	*Solanum lycocarpum*	Y	Y	Least Concern	90	4	1	86	95.6	0	BRA003	CENARGEN
Vegetables	*Apium australe*	Y	Y		86	3	1	84	97.7	0	CHL171	SAG
Vegetables	*Chlorophytum borivilianum*		Y	Critically Endangered	37	1	37	37	100	0	IND001	NBPGR
Vegetables	*Helosciadium repens*	Y			35	1	35	35	100	6	DEU502	BOGOS
Herbs and spices	*Alpinia officinarum*				73	1	73	73	100	0	VNM049	PRC
Herbs and spices	*Lippia dulcis*		Y		54	1	54	54	100	0	MEX006	BANGEV
Stimulants	*Ilex guayusa*	Y		Least Concern	161	3	1	157	97.5	0	ECU098	USFQ
Stimulants	*Coffea mauritiana*	Y		Vulnerable	95	3	1	93	97.9	0	FRA254	IRD
Pseudo-cereals	*Cycas micronesica*			Endangered	23	1	23	23	100	0	USA047	MIA

Notes: CWR = crop wild relatives. WFP = wild food plants. Holding institute acronyms are explained in Appendix 5.

categories of major concern (IUCN, 2022).[38] A subset of these, all of which are CWR, is presented in Table 3.20. It is noteworthy that the number of accessions per species within genebanks is low overall – three on average. A total of 1 166 species have one accession each, while one species, *Aegilops sharonensis*, a wild relative of wheat that is classed as Vulnerable by IUCN and is a source of resistance to diseases and insects and tolerant of salt, drought and nutrient deficiencies (Wang *et al.*, 2021), has 2 784 accessions, 93 percent of which are conserved in one genebank only.[39] The distribution of this threatened germplasm among genebanks is biased towards Northern America, Europe and Asia, which together account for 91 percent of the species and 82 percent of the accessions conserved.[40]

3.4.6 Gaps in collection coverage

Ensuring adequate coverage of the genetic diversity in germplasm collections, especially at the global level, is important for the conservation and sustainable use of PGRFA. Identification of gaps in collections has therefore received increasing attention. New tools and methods have been developed to assess these gaps, including through the study of the genetic diversity and geographical representation in collections (e.g. in Ramirez-Villegas *et al.*, 2010, 2020).

Several countries report gaps in their collections, including gaps in collections of FV/LR (Armenia, Botswana and Malaysia), priority crops (Benin), food crops (Brazil, Ghana and Guyana), CWR (Peru, Malaysia and the Kingdom of the Netherlands), fruit species (Germany), small grains (Serbia), vegetatively propagated crops (Namibia) and a number of important species (Republic of Moldova).

[38] Critically Endangered; Endangered; Extinct in the Wild; Near Threatened; Vulnerable.

[39] Lieberman Germplasm Bank, Institute for Cereal Crops Improvement, Tel Aviv University. Note that only 7 percent of the *A. sharonensis* collection is safety duplicated.

[40] Holdings in these three regions account for 64 percent of the total germplasm conserved.

TABLE 3.20
Selected species conserved *ex situ* and listed in the International Union for Conservation of Nature categories of major concern

Species	Total number of accessions	IUCN Red List category
Aegilops sharonensis	2 784	Vulnerable
Malus sieversii [(1)]	1 947	Vulnerable
Cicer reticulatum [(2)]	1 192	Near Threatened
Pinus albicaulis	926	Endangered
Aegilops bicornis	461	Near Threatened
Cicer bijugum	170	Endangered
Avena murphyi	140	Endangered
Coffea arabica	131	Endangered
Coffea mauritiana	94	Vulnerable
Solanum okadae	89	Endangered
Pistacia vera	88	Near Threatened
Mentha cervina	81	Near Threatened
Coffea macrocarpa	63	Vulnerable
Solanum alandiae [(3)]	63	Near Threatened
Solanum trifidum	57	Near Threatened
Amblyopyrum muticum [(4)]	47	Endangered
Solanum chmielewskii	44	Endangered
Allium altaicum	44	Near Threatened
Brassica villosa	42	Near Threatened
Solanum oxycarpum	42	Endangered
Brassica villosa	42	Near Threatened
Vigna exilis	42	Near Threatened
Vigna grandiflora	42	Near Threatened
Pistacia atlantica	39	Near Threatened
Solanum neocardenasii	39	Endangered
Solanum wittmackii	39	Endangered
Helianthus exilis	35	Near Threatened
Solanum lycopersicoides	35	Endangered
Solanum schenckii	35	Endangered
Arachis villosa	33	Near Threatened
Dioscorea sambiranensis	33	Near Threatened
Solanum chmielewskii	33	Endangered
Brassica rupestris	32	Near Threatened

Notes: [(1)]Synonym of *Malus domestica*. [(2)]Synonym of *Cicer arietinum* subsp. *reticulatum*. [(3)]Synonym of *Solanum brevicaule*. [(4)]Synonym of *Aegilops mutica*. IUCN = International Union for Conservation of Nature

The global strategies for the long-term conservation and use of crop-specific gene pools developed under the leadership of the Crop Trust offer a reliable source of information on gaps in crop collections of global importance. For most of the crop gene pools for which a global conservation strategy has been developed, specific gaps in the existing (global) collections have been highlighted and may serve as a guide for setting new collecting priorities and/or promoting collaboration in targeted collecting. A summary of crop gene pool-specific gaps listed in published crop strategies is presented in Appendix 4.

3.4.7 Trends in *ex situ* conservation capacities

The sustainability of safe, efficient and effective long-term conservation depends on the availability of the financial resources, skilled staff and infrastructure needed for processing, storing and monitoring activities in genebanks. Countries were asked to report on the state of capacities at national genebanks in terms of infrastructure and human and financial resources in 2019 as compared to 2010. Table 3.21 summarizes the results for each element of capacity by region. Figure 3.6 presents a regional breakdown of the weighted average status of the different capacity elements in 2019 relative to the situation in 2010.

Globally, there was an overall increase in the various components of capacity between 2010 and 2019, with notable differences between regions. Europe, Northern Africa and sub-Saharan Africa showed increases in all three components of capacity. Although the 2010 baseline does not necessarily indicate whether the capacities were adequate at that time, values below the baseline probably have a negative impact on conservation activities in the respective countries.

Although human resources capacity at national genebanks increased slightly overall, it decreased in 39 percent of the reporting countries and remained unchanged in 17 percent (Table 3.21). Latin America and the Caribbean had the highest proportion of genebanks whose human resources capacity declined (62 percent). In Asia, although half the reporting countries indicate an increase in staff capacity, the regional weighted average declined relative to 2010 as a result of reduced capacity in national genebanks with large collections. Conversely, in sub-Saharan Africa, where seven countries report an increase in staff capacity and seven a decrease, overall capacity showed a significant increase because of positive changes in the two largest genebanks (Ethiopia and Kenya).

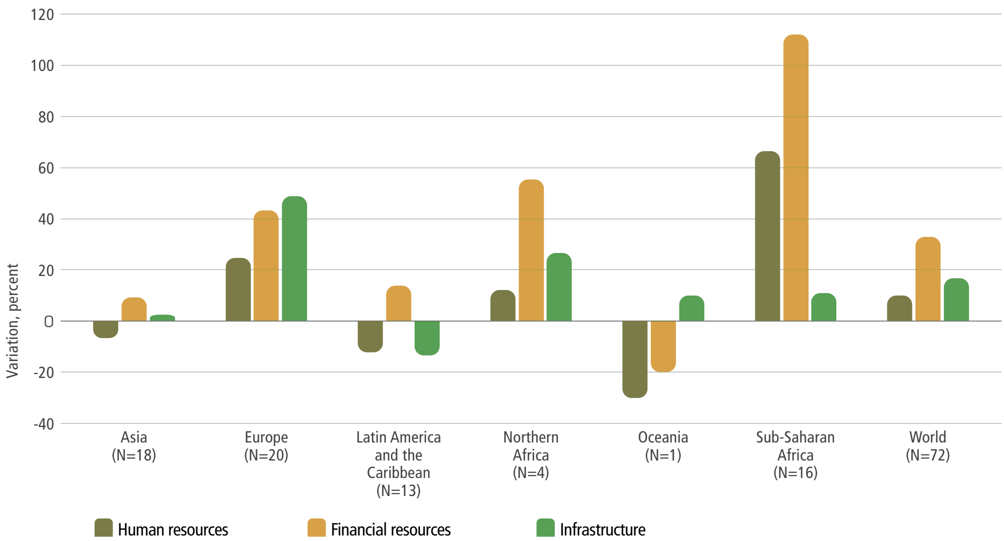
With regard to financial resources, 35 percent of reporting countries indicate a decrease in

TABLE 3.21
Direction of trends in the status of human resources, financial resources and infrastructure at national genebanks between 2010 and 2019

Region	Number of countries								
	Human resources			Financial resources			Infrastructure		
	↘	=	↗	↘	=	↗	↘	=	↗
Asia	7	2	9	4	2	12	3	5	10
Europe	5	6	9	3	2	15	3	6	11
Latin America and the Caribbean	8	0	5	7	0	5	7	2	3
Northern Africa	0	2	2	0	2	2	0	2	2
Oceania	1	0	0	1	0	0	0	0	1
Sub-Saharan Africa	7	2	7	10	0	6	8	2	6
World	28	12	32	25	6	40	21	17	33

Notes: ↗ indicates increased capacity in 2019 as compared to 2010; = indicates no change in capacity; ↘ indicates decreased capacity.

FIGURE 3.6
Variation in the status of human resources, financial resources and infrastructure at national genebanks in 2019 relative to 2010



Notes: Weighted regional and global averages produced by using national *ex situ* holdings as a weighting factor against the regional and global *ex situ* holdings, respectively. N indicates the number of reporting countries.

2019 relative to 2010, 56 percent report an increase and 9 percent report no change. Overall, financial capacity weighted by *ex situ* collection size improved in all regions except Oceania.[41] The region with the highest proportion of reporting countries where funding increased was Europe (75 percent), while the regions with the highest proportions of reporting countries where funding decreased were sub-Saharan Africa (63 percent) and Latin America and the Caribbean (58 percent). As in the case of human resources, a large increase in the availability of financial resources at the largest genebank in sub-Saharan Africa (over 400 percent) doubled the weighted regional average relative to that of 2010. Concerningly, in 16 percent of reporting countries, financial resources fell by 50 percent or more. One of these countries was in Asia,[42] five in sub-Saharan Africa[43] and five in Latin America and the Caribbean.[44] National genebanks in countries experiencing a reduction in funding availability compared to 2010 also had to cope with an overall 16 percent increase in the number of accessions conserved (from 458 458 to 533 060).

With respect to infrastructure capacity, 47 percent of reporting countries (conserving a total of about 900 000 accessions – an increase of 18 percent compared to 2010) indicate improvements in 2019 relative to 2010. However, almost one-third of reporting countries (conserving a total of more than 476 000 accessions or 15 percent more than in 2010) indicate that the state of their infrastructure

[41] Reported only by Papua New Guinea.

[42] Myanmar.

[43] Botswana, Madagascar, Togo, Uganda, Zambia.

[44] Cuba, Ecuador, Guyana, Mexico, Trinidad and Tobago.

declined. Infrastructure remained unchanged in the remaining countries. These countries also experienced an increase of 15 percent in their total germplasm holdings, which amounted to almost 715 000 accessions in 2010. The two regions where the largest numbers of reporting countries enhanced their national genebank facilities were Europe (11 countries) and Asia (10 countries).[45] Conversely, 58 percent of reporting countries in Latin America and the Caribbean indicate a deterioration of their infrastructure capacity, despite a 28 percent increase in their genebank holdings (to 160 086 accessions). Similarly, in sub-Saharan Africa, 50 percent of reporting countries indicate reduced infrastructure capacity, despite conserving 88 953 accessions in 2019, 9 percent more than in 2010. Overall, these figures are concerning, as high levels of capacity reduce the risk of unwanted losses of genetic resources conserved *ex situ*, some of which may no longer exist at the original collecting sites.

Significant improvements and problems reported by countries can be summarized as follows. Seventeen countries[46] report improvements in *ex situ* seed storage facilities. Twenty-five countries[47] provided information on the problems and needs of their respective storage facilities, which included the need to increase and modernize storage capacity and facilities, to replace lost storage infrastructure (rather frequently reported), to re-establish or restructure the national genebank, to address power cuts and erratic power supply, to acquire new laboratory equipment and to establish in-house (germination) testing facilities.

The SoW2 indicated that there had been an increase in storage capacity during the respective reporting period, particularly as a result of new genebanks being built. However, the situation at the end of the current reporting period seems to be less positive. Many countries report that they either do not have the type of storage facilities they need (predominantly long-term facilities) or that their equipment is outdated and/or malfunctioning. Linked to this is the fact that many genebanks have difficulties processing materials in a timely manner – the capacity of their testing facilities is insufficient and/or they lack qualified staff. However, a number of countries also report that they have been able to increase the capacity of their medium- and long-term storage facilities (e.g. Brazil, Japan, Türkiye and Uzbekistan), that new genebanks or facilities have been built (e.g. Japan, Lebanon and Poland) and/or that they have been able to streamline procedures. Some countries (e.g. Lebanon and the Republic of Moldova) also mention that they have been able to attract project funding to improve their conservation infrastructure.

It should be noted that several countries report a lack of sufficient funding to allow secure and smooth operation of their storage facilities (e.g. Indonesia, Mongolia, Spain and Yemen). Many more countries, particularly countries on the African continent, note a lack of adequate funding for their *ex situ* conservation operations, including for collecting, monitoring and regeneration/multiplication (see Section 3.13).

3.4.8 Update on genebank and collection management practices

Over the past several decades, *ex situ* conservation has substantially and steadily increased across the world as a way of conserving PGRFA safely and effectively. Genebanks have been built and collections established for all the major crops and their wild relatives, as well as for minor crops and WFP. More recently, a number of tools and practices that facilitate germplasm management have been adopted (see Engels and Ebert, 2021). To promote best practices, genebank conservation standards have been developed and applied. The *Genebank Standards for Plant Genetic Resources for Food*

[45] Germplasm holdings of 524 631 and 159 330 accessions, respectively, in these groups of countries.

[46] Belarus, Brazil, Costa Rica, Czechia, Finland, India, Japan, Lebanon, Mali, Poland, Republic of Moldova, Serbia, Tajikistan, Tunisia, Uzbekistan, Yemen, Zimbabwe.

[47] Albania, Argentina, Azerbaijan, Botswana, Cameroon, Cuba, Ghana, Guinea, Guyana, Kenya, Mali, Madagascar, Myanmar, Namibia, Niger, Philippines, Republic of Moldova, Romania, South Africa, Sudan, Togo, Trinidad and Tobago, Uganda, United Republic of Tanzania, Zimbabwe.

and Agriculture (FAO, 2014) and three practical guides on their application, respectively covering conservation of orthodox seed in genebanks (FAO, 2022a), conservation in field genebanks (FAO, 2022b) and conservation via in vitro culture (FAO 2022c), have been published to support countries and genebanks in their conservation efforts.

The increasing use of barcoding technology greatly facilitates the effective, efficient and safe management of accessions in genebanks (Avagyan *et al.*, 2020). Molecular tools, such as next-generation sequencing and genotyping-by-sequencing, combined with informatics, have enabled scientists to enhance the quality, efficiency and cost-effectiveness of genebank operations and to deepen scientific knowledge of genebank holdings (see Box 3.3). Genomic information provides a rationale for reducing redundancies within and across crop collections, thus limiting the size of collections and making long-term conservation more cost effective (Singh *et al.*, 2019). It can also facilitate genetic gap analyses to guide future collecting missions and acquisitions. Experiments with the seeds of several vegetable crops have shown that RNA integrity declines with storage time in dry seeds (Fleming, Hill and Walters, 2019), and assessment of RNA integrity can thus be used to predict the onset of viability decline. New developments in seed storage, such as initial high-temperature drying (Whitehouse, Hay and Ellis, 2018), will help enhance seed longevity and thus make conservation more effective.

In recent years, the CGIAR Genebank Platform under the coordination of the Crop Trust implemented several quality-management mechanisms that enhanced effective online reporting, performance and quality management and included a periodic audit, external review and validation (Lusty, van Beem and Hay, 2021). These mechanisms helped genebanks manage regeneration backlogs, avoid mistakes in the handling of accessions, minimize losses and reduce duplication of efforts, facilitating continuous improvements and compliance with the FAO Genebank Standards and other relevant best practices. As a result, CGIAR (CGIAR Genebank Platform, 2021b) and other genebanks that adopted these quality-management tools, for instance, CePaCT in the South Pacific, WorldVeg and SPGRC, significantly improved their performance and the conservation status of their collections.

3.4.9 Comparison between the second and the third State of the World Reports

Comparing the *ex situ* holdings reported for 2022 with those reported for 2009 in the SoW2 is not straightforward: different numbers of countries reported for the two assessments, different sources and types of collections were reported, and various institutional changes, including relocation, merging or redistribution of germplasm collections, occurred in countries during the intervening period.

Number of reporting countries

A total of 169 countries, four regional centres and 13 international centres reported on their *ex situ* collections for either the SoW2 or the SoW3. However, only 106 countries, four regional centres and 12 international centres reported for both assessments. The regional distribution of the 106 reporting countries is summarized in Table 3.22. A key factor that explains most of the downward trend observed in the reporting countries is the difference between the types of data reported for the two assessments. Accession-level data were reported for the SoW3 while metadata were reported for the SoW2, namely number of accessions of particular genera, species or plant groups, distinct biological status and specific country of origin (see below).

Information on *ex situ* collections for the SoW2 was compiled from over 400 information sources accessed by FAO via direct data surveys/questionnaires, personal communications and data harvesting from country reports, scientific articles and inventories. Given the diversity of sources, the information compiled consisted of metadata represented by the number of accessions conserved at the genebank level for

Box 3.3
The Future Seeds genebank

Future Seeds is the new eco-efficient genebank of the Alliance of Bioversity International and CIAT in Colombia, inaugurated in March 2022. It is the first genebank in the world to achieve the platinum level Leadership in Energy and Environmental Design (LEED) certification. It houses the largest collections of beans (*Phaseolus* spp.), cassava (*Manihot* spp.) and tropical forages (including grasses and legumes), totalling around 66 000 materials, which are held in trust for more than 140 of their countries of origin. The building comprises facilities including seed vaults with laboratories for seed handling, a herbarium, laboratories for *in vitro* conservation and cryopreservation, a germplasm health laboratory, and a "digital genebank" for DNA collections and genomic data analyses. The digital genebank aims to bridge the gap between the conservation of crop diversity and plant breeding, while also helping genebank curators to optimize the composition of collections.

Over recent years, the digital genebank has focused on generating genomic sequence information (or digital sequence information – DSI) for the three collections. The cassava collection has been almost completely genotyped, and more than 10 000 common bean accessions were being genotyped in 2024 using a reduced representation sequencing approach. In addition, sequencing of all accessions of the two forage genera that are being genetically improved by the Tropical Forages Program (*Urochloa* and *Megathyrsus* spp.) has been completed. Cassava DSI data have shed light on the genetic composition of the cassava collection in comparison to the cassava collection at the International Institute of Tropical Agriculture (IITA), which was genotyped on the same platform. This analysis has also identified genetically redundant accessions, enabling the cassava curator to prioritize accessions for rejuvenation and cryopreservation efforts (Carvajal-Yepes *et al.*, 2024). DSI data are being co-analysed with climate data to mine the cassava and bean collections for genetic variants associated with hot and dry climates as part of a CGIAR-wide "allele-mining" project that aims to develop climate-ready crop varieties (CIMMYT, 2024). Integrating DSI with disease data reported by previous genebank users (Sheat *et al.*, 2019) has enabled Future Seeds to identify novel genetic variants associated with resistance to an important cassava disease (Ospina Colorado *et al.*, 2024).

Future Seeds also serves as a collaboration platform for the scientific community dedicated to plant genetic resources. It is coordinating, in collaboration with the International Maize and Wheat Improvement Center (CIMMYT), a community of practice for Latin America and the Caribbean that focuses on enhancing DSI capacities for conserving and utilizing plant genetic resources, particularly those that originated in the region. The community of practice was first convened in 2021 following a survey of 48 stakeholders from 14 countries and 33 institutions that established that the majority of national genebanks were interested in using DSI for genetic diversity studies, trait discovery, association analyses and germplasm characterization efforts. In 2022, it organized two virtual and one in-person workshop to address the key challenges and common priorities identified in the survey, including sample traceability, genotyping methods, and tools for DSI curation, analysis and interpretation. Workshop participants also had the opportunity to generate DSI for their own collections of crops that are commonly conserved in the region. Two additional virtual meetings and one in-person workshop were held in 2023 to discuss experiences of using DSI both independently and collectively for crops conserved by multiple genebanks. The latter enabled, for the first time, comparisons of crop diversity conserved by multiple genebanks in Latin America and the Caribbean. These collective efforts have fostered a collaborative spirit that has been further leveraged to address other genebank-related topics prioritized by community of practice members on a regular basis, such as gap analyses and best practices for the regeneration and conservation of seed collections.

Sources: Carvajal-Yepes, M., Ospina, J.A., Aranzales, E., Velez-Tobon, M., Correa Abondano, M., Manrique-Carpintero, N.C. & Wenzl, P. 2024. Identifying genetically redundant accessions in the world's largest cassava collection. *Frontiers in Plant Science*, 14: 1338377. https://doi.org/10.3389/fpls.2023.1338377; CIMMYT (International Maize and Wheat Improvement Center). 2024. *Mining useful alleles for climate change adaptation from CGIAR genebanks*. In: *CIMMYT*. [Cited 31 May 2024]. https://www.cimmyt.org/projects/mining-useful-alleles/; Ospina Colorado, J.A., Lopez Alvarez, D.C., Gimode, W.R.A., Wenzl, P. & Carvajal Yepes, M. 2024. Data: *Genome-wide association study of cassava brown streak disease resistance in cassava germplasm conserved in South America*. Harvard Dataverse. https://doi.org/10.7910/DVN/H4PDE5; Sheat, S., Fuerholzner, B., Stein, B. & Winter, S. 2019. Resistance against cassava brown streak viruses from Africa in cassava germplasm from South America. *Frontiers in Plant Science*, 10: 567. https://doi.org/10.3389/fpls.2019.00567 and personal communication with Monica Carvajal Yepes, Peter Wenzl and Isabel Lopez Noriega (Alliance of Bioversity International and CIAT).

TABLE 3.22
Regional distribution of countries reporting on *ex situ* collections for both the Second and the Third State of the World reports

Region	Number of reporting countries		
	2009 (SoW2)	2022 (SoW3)	2009 and 2022 (SoW2 & SoW3)
Northern Africa	6	5	5
Sub-Saharan Africa	36	23	21
Northern America	2	2	2
Latin America and the Caribbean	33	19	19
Oceania	13	3	3
Asia	35	27	24
Europe	32	37	32
Total	157	116	106

Notes: SoW2 = *The Second Report on the State of the Worlds' Plant Genetic Resources for Food and Agriculture*; SoW3 = the present report.

rather heterogeneous and non-standardized data categories, including plant groups (cereals, forages, vegetables, etc.), combinations of these, and distinct combinations of taxon, biological status and country of origin. Both active or breeders' collections and base collections were reported without distinction, and in a number of cases collections were reported and accounted for more than once.

Information on *ex situ* holdings for the SoW3 has benefited from standardization and other improvements in documentation made by genebanks and associated with the development of national germplasm inventories and conservation strategies. The information on *ex situ* holdings for the SoW3 relies on accession-level data reported by countries on base collections and only those active collections that will eventually become part of national base collections, as per the data requirements specified in the metadata sheet of SDG Indicator 2.5.1.a (United Nations, 2024). The application of these criteria helped to reduce data redundancy at the national level significantly as compared to the SoW2.

Institutional changes

During the period between 2009 and 2022, institutional changes and new policies and strategies led to the reorganization of several national germplasm collections. Operations at more than 55 of the genebanks that contributed information to SoW2 were reportedly discontinued, and almost 80 genebanks were either merged with other genebanks or had their control assigned to other institutions.

National collections

Across the 106 countries that contributed to both reports, only 651 genebanks (44 percent) out of the 1 465[48] whose germplasm holdings were accounted for in the SoW2 could be matched with genebanks considered in the SoW3, 602 (74 percent) of which were matched to genebanks that contributed to the SoW2 (see Table 3.23). These "matching genebanks" are, however, quite representative in that they hold a significant proportion of the germplasm conserved in the respective countries in 2009 and 2022 (72 percent and 84 percent, respectively).

Compared to the SoW2, a modest positive change (+6 percent) occurred in the national germplasm holdings in these countries and genebanks (Table 3.23). Increases in germplasm holdings occurred in Northern Africa, where four out of five reporting

[48] Holding 5 420 812 accessions.

TABLE 3.23
Regional comparisons of the numbers of reporting genebanks, matched genebanks and total accessions in 2009 and 2022

Region	Number							
	Countries	Genebanks (total)		Genebanks (matching)		Accessions		
		2009 (SoW2)	2022 (SoW3)	2009 (SoW2)	2022 (SoW3)	2009 (SoW2)	2022 (SoW3)	Change (%)
Northern Africa	5	16	5	14	5	49 535	130 391	163
Sub-Saharan Africa	21	109	53	57	38	212 301	209 081	-2
Northern America	2	87	30	43	30	622 262	705 699	13
Latin America and the Caribbean	19	333	203	120	129	508 891	430 306	-15
Oceania	3	40	11	11	9	202 289	335 896	66
Asia	24	359	101	112	78	1 009 705	996 585	-1
Europe	32	521	416	294	313	1 286 639	1 300 897	1
Total	**106**	**1 465**	**819**	**651**	**602**	**3 891 622**	**4 108 855**	**6**

Notes: SoW2 = *The Second Report on the State of the Worlds' Plant Genetic Resources for Food and Agriculture*; SoW3 = the present report.

countries established or significantly strengthened their national genebanks, in two out of the three reporting countries in Oceania, and, to a lesser extent, in both countries in Northern America.

Significant reductions were observed in Latin America and the Caribbean, where holdings in 13 out of 19 countries dropped, with changes greater than 70 percent in three countries and greater than 30 percent in an additional four. In sub-Saharan Africa, despite a negligible average change, five countries had reductions of more than 50 percent in their germplasm holdings, one of which had a reduction of 79 percent and another a reduction of 90 percent.

In general, minor differences between the germplasm holdings reported for the SoW2 and those reported for the SoW3 resulted from the rationalization of countries' conservation efforts. However, at least 406 collections of more than 75 accessions each, totalling over 321 300 accessions from 195 crop genera, held in 2009 by more than 191 genebanks in 64 countries[49] were no longer reflected in the national holdings of the respective countries in 2022. This may be a result of reporting omissions, losses or both. Notably, 47 percent of the missing collections were conserved in field collections, a method that is overall more costly to manage and more vulnerable to biotic and abiotic stresses. Fruit plants and nuts were the group most represented (27 percent), followed by vegetables, roots and tubers (17 percent) and cereals (9 percent).

[49] Northern Africa (2 countries); sub-Saharan Africa (13 countries); Northern America (1 country); Latin America and the Caribbean (15 countries); Oceania (3 countries); Asia (13 countries); Europe (17 countries).

International collections

The total number of accessions conserved by the 12 international centres that reported for both global assessments, increased by approximately 19 percent between 2009 and 2022. The germplasm holdings at ICRAF, ITC – Bioversity and IITA each grew by more than 37 percent. The establishment of the *ex situ* collections at ICRAF alone explains the overall growth in the number of genera conserved in the international centres and one-third of the increase in the number of species conserved. Notably, at IITA the overall intergeneric diversity was reduced in favour of greater coverage of intraspecific diversity of mandated field crops.

TABLE 3.24
Comparison between the collections maintained by regional and international centres in 2009 and 2022

Centres		2009 (No.)			2022 (No.)			Change (%)		
		Genera	Species	Accessions	Genera	Species	Accessions	Genera	Species	Accessions
Regional	CATIE	106	215	11 025	211	321	10 950	99	49	–1
	CePaCT	13	18	1 510	18	23	2 520	38	28	67
	NordGen	162	350	29 312	212	432	33 306	31	23	14
	SPGRC	85	138	10 551	37	41	11 326	–56	–70	7
	Subtotal	**319**	**672**	**52 398**	**424**	**763**	**58 102**	**33**	**14**	**11**
International	AfricaRice	1	5	21 527	1	7	21 815	0	40	1
	CIAT	130	765	64 466	126	760	66 556	–3	–1	3
	CIMMYT	11	37	173 571	12	53	213 600	9	43	23
	CIP	11	210	15 046	11	248	16 364	0	18	9
	ICARDA	88	476	132 793	108	553	152 286	23	16	15
	ICRAF	3	6	1 785	101	184	15 232	3 267	2 967	753
	ICRISAT	17	169	128 961	18	186	146 534	6	10	14
	IITA	71	129	27 596	22	83	37 757	–69	–36	37
	ILRI	396	1597	18 763	412	1599	18 639	4	0	–1
	IRRI	9	32	109 161	8	33	132 604	–11	3	21
	ITC – Bioversity	2	20	1 207	2	33	1 693	0	65	40
	WorldVeg	163	321	56 522	140	325	68 727	–14	1	22
	Subtotal	**615**	**2 972**	**751 398**	**674**	**3 323**	**891 807**	**10**	**12**	**19**
Total		**770**	**3 392**	**803 796**	**929**	**3 864**	**949 909**	**21**	**14**	**18**

Regional collections
Genera and species coverage in all regional centres other than SPGRC increased notably between 2009 and 2022. Accession holdings increased by 11 percent overall in the four regional genebanks, with CePaCT reporting the largest percent increase. At CATIE, there were significant reductions in the sizes of the *Capsicum* (-25 percent), *Cucurbita* -19 percent) and *Solanum* (-16 percent) collections. Opposite trends were reported for the coffee collections, which increased by 8 percent to almost 2 000 accessions, and the cocoa collection, which increased by 75 percent to 1 245 accessions.

3.4.10 Summary assessment

A total of 5.9 million accessions from more than 7 300 genera and almost 52 000 species are conserved under medium- and long-term storage conditions, as reported by 869 national, regional and international genebanks in 2023 for the indicator that monitors progress towards the plant component of SDG Target 2.5. These include 5 million accessions conserved in 852 genebanks in 116 countries, representing more than 7 281 genera and 50 990 species. The overall growth in germplasm holdings relative to those reported in the SoW2 is estimated at 8 percent, specifically 6 percent in national genebanks, 11 percent in regional genebanks and 19 percent in international genebanks. Compared to 2014, the number of accessions of CWR, WFP and other wild flora conserved *ex situ* has increased by 17 percent, 39 percent and 26 percent, respectively.

The proportions of wild species, FV/LR, breeding/research materials and advanced cultivars among the total number of accessions did not change significantly between the two reporting periods. Crop groups that contain species that are the focus of strong breeding and research efforts, often including those of significant dietary importance, generally have the highest number of accessions, illustrating the impact that germplasm users have on the priorities of genebanks. The changes in the composition of *ex situ* collections in terms of biological types since 2014 are relatively small, even with an increase of more than 650 000 accessions (21 percent) across the various crop groups. There have been no dramatic changes in the ranking and status of the 50 major food and other crop gene pools of importance to global food security.

In most countries, field genebanks are mainly used to conserve recalcitrant-seeded species and vegetatively propagated crops, and are the only way in which these species can be conserved over the long term. As field genebanks are highly vulnerable to abiotic and biotic stresses and require year-around attention, including cultivation management, the need to reliably back up these collections through *in vitro* culture and/or cryopreservation is clear. It should be noted, however, that reliable *in vitro* and cryopreservation protocols have not yet been established for many crop species. Encouragingly, countries report an increasing use of these techniques. More countries are recognizing that this is feasible, and many genebanks have started to install facilities and/or seek collaboration with partners at the country level that will allow them to benefit from the advantages that these techniques provide.

The increasing use of molecular tools in germplasm management and the adoption of standardized information-management systems have increased capacity to rationalize conservation activities. There has, therefore, been some progress in terms of eliminating unwanted duplication within collections. The use of data documentation standards and the publication of data on web-based portals contribute to the rationalization of redundancies among collections. The significant increase in the estimated uniqueness in global germplasm holdings since the time of the SoW2 is also probably driven by efforts made at the national level to increase efficiency as well as by the more focused coverage of SDG Indicator 2.5.1.a, which excludes germplasm in active collections if already part of the reported base collections.

Although there was an overall increase in financial, technical and human resource capacities for conservation of PGRFA at the global level between 2010 and 2019, the difficulties that many countries report with regard to sustaining conservation activities are grounds for concern. Reporting countries note the benefits of regional/international collaboration and coordination of conservation efforts, the sharing of long-term conservation facilities, the rationalization of collections and the improvement of collaboration among stakeholders.

The importance of standards, practical guides and standardized operational procedures as well as the sharing of knowledge and experience among members of the gene-banking community is increasingly being recognized. Adhering to such standards increases transparency and accountability and makes it easier to build trust among curators and other stakeholders and thus to promote collaboration and, ultimately, germplasm use. It is, however, important to ensure that as many genebanks and collections as possible are enabled to take part in such developments.

3.5 Safety duplication of stored material

The safety duplication of accessions is an essential security measure for genebanks. The FAO Genebank Standards recommend that a sample of every original accession should be stored in a geographically distant area under equivalent or better conditions than those in the original genebank and that the duplicated sample should be accompanied by the relevant associated information (FAO, 2014). For species producing orthodox seeds, safety duplication at other genebank facilities is relatively straightforward, although it has still only partially been achieved. For clonal species and species producing recalcitrant seeds, genebanks are increasingly backing up field genebank accessions via *in vitro* culture or cryopreservation (see Section 3.4.5). Several countries regard accessions collected within their territories as part of international collecting projects (e.g. the Crop Trust's Crop Wild Relatives Project) or kept in international collections (e.g. CGIAR centres and MSB) as being under a form of safety duplication. The arrangements among SADC member countries to deposit their germplasm collections at the regional genebank, SPGRC, offer a strategic form of safety duplication.

For orthodox seeds, SGSV serves as an additional backup that provides genebanks with safe, free and long-term storage of safety duplicates. The success achieved in terms of deposits over the years proves the value of this initiative. A global cryopreservation facility providing similar services for vegetatively reproducing species or species producing recalcitrant seeds has been proposed (Acker *et al*., 2017).

As reported for SDG Indicator 2.5.1.a at the end of 2022, 41 percent of all *ex situ* holdings, or 2 453 458 accessions held by 341 genebanks in 85 out of 116 countries and 15 out of 17 regional and international centres,[50] were safety duplicated in other genebanks or at SGSV. This represents a significant increase relative to the situation in 2014, when 788 750 accessions, or 15 percent of the total, were reported to be safety duplicated by the respective countries and centres. The percentage of safety duplication is relatively high among international centres (79 percent, as compared to 48 percent in 2014) and regional centres (60 percent), while it is below 24 percent in the case of national collections, up from 10 percent in 2014.[51] Across regions, the level of safety duplication varies significantly: lowest is in Africa and Asia, and highest is in Northern America and Oceania (Table 3.25).

Overall, 69 percent of all safety-duplicated accessions are conserved at the origin as seed, 2.3 percent in field collections and less than 1 percent *in vitro*. The remaining 28 percent are mainly represented by the collection at the Nottingham Arabidopsis Stock Centre, where samples are held under cryopreservation. Safety duplication is reported for about 36 percent of all accessions stored as seed, 13 percent of those conserved in field genebanks, 32 percent of those held in *in vitro* collections and 98 percent of those cryopreserved. About 39 percent of cereal accessions are safety duplicated, 40 percent of pulse accessions, 37 percent of forage accessions, 29 percent of vegetable accessions, and 27 percent of root and tuber accessions. The least duplicated collections are those of fruit plants, pseudo-cereals, stimulants and nuts, all of which have less than 16 percent duplication. In taxonomic terms, safety-duplicated diversity includes 2 534 genera and 12 382 species. Safety duplicates are held by 348 genebanks in 50 countries, 13 regional and international centres and SGSV.

At the end of 2022, 93 genebanks from 63 countries, three regional centres and 12 international centres had deposited 1 215 536 samples belonging to 1 179 006 accessions at SGSV. These include 1 065 990 accessions reported for SDG Indicator 2.5.1.a (18 percent of the total 5.9 million) and represent 60 percent of all safety duplicated

TABLE 3.25
Percentage of total *ex situ* holdings safety duplicated, by region

Region	Total accessions	Accessions safety duplicated (%)
Northern Africa	130 391	5
Sub-Saharan Africa	214 871	10
Northern America	705 699	62
Latin America and the Caribbean	476 387	20
Oceania	336 282	38
Asia	1 041 069	7
Europe*	1 387 371	19

Note: *The collection at the Nottingham Arabidopsis Stock Centre is excluded.

50 The *ex situ* collections held by CePaCT and ICBA reportedly have no accessions safety duplicated.
51 The Nottingham Arabidopsis Stock Centre is excluded.

accessions, excluding the collection at the Nottingham Arabidopsis Stock Centre. A list of the 15 largest depositors at SGSV, each with more than 20 000 samples deposited, is presented in Table 3.26.

In addition to the safety-duplicated accessions, it is worth noting that there are 391 598 accessions that are reportedly not safety duplicated externally but are conserved in different storage collections in the same genebank.

3.5.1 Situation in the regions

Sub-Saharan Africa

Fourteen countries provided information on the status of the safety duplication of their collections. The Niger and Zimbabwe report that they have been able to maintain or even improve the level of their safety duplication. Benin, Ghana, Kenya, Mali and Uganda mention duplication at one or more of the CGIAR centres. Botswana and South Africa mention safety duplication of part of their collections at SPGRC. Kenya and Uganda report safety duplication at SGSV. Kenya and Mali also mention safety duplicating germplasm at the MSB and at the University of Copenhagen, respectively. Ethiopia reports that it has no functional safety duplication facility in place. Madagascar reports that it safety duplicates part of its collections elsewhere in the country in response to climate change.

Northern Africa

Egypt reports that it is waiting to start systematic safety duplication; its national genebank stores duplicates from the Egyptian Desert Bank in Sheikh Zuweid, Sinai. Tunisia reports the creation of national collections of different species and that its national genebank ensures safety duplication of its field genebank collections.

Latin America and the Caribbean

Several countries report various levels of safety duplication activities, including Chile, Ecuador, Guyana, Mexico, Trinidad and Tobago, and Uruguay. Brazil reports that its national genebank stores safety duplicates from other Brazilian genebanks and from international genebanks. Colombia mentions that it has developed new

TABLE 3.26

The 15 largest depositors at the Svalbard Global Seed Vault, 2024

Depositor institute	Number of accessions	Number of taxa
International Maize and Wheat Improvement Center (CIMMYT)	167 665	42
National Plant Germplasm System (NPGS), United States of America	154 818	2 160
International Rice Research Institute (IRRI)	122 155	51
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	117 713	36
International Center for Agricultural Research in Dry Areas (ICARDA)	104 260	437
Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Germany	61 605	3 900
International Center for Tropical Agriculture (CIAT)	57 342	702
The World Vegetable Center	39 766	254
Australian Pastures Genebank (APG)	34 491	1 193
Plant Gene Resources of Canada (PGRC)	31 444	456
National Institute of Agricultural Sciences (NIAS). Rural Development Genebank, Republic of Korea	30 272	79
Australian Grains Genebank (AGG)	27 150	265
Nordic Genetic Resource Center (NORDGEN)	25 037	6 30
Centre for Genetic Resources, the Netherlands (CGN)	21 354	409
AfricaRice	20 112	12

Source: SGSV (Svalbard Global Seed Vault). 2024. In: *Svalbard Global Seed Vault*. [Cited 10 February 2024]. https://seedvault.nordgen.org strategies and undertaken research on the development of new conservation techniques to ensure safe and viable safety duplication in the long term. Cuba reports that it has no safety duplication strategy in place and that its biggest constraint is a lack of sufficient and adequate storage capacity.

Northern America
Canada reports that more than 30 percent of its seed collection is safety duplicated outside the country, including at Fort Collins, United States, and at SGSV.

Asia
Bangladesh, Indonesia, Jordan, Lebanon, Mongolia, the Philippines, Tajikistan and Yemen report safety duplication of accessions of the respective mandate crops at CGIAR centres. Jordan and Lebanon report that they also store duplicates at the MSB. Lebanon, Mongolia, Pakistan and Tajikistan report duplication of materials at SGSV. Azerbaijan, Indonesia, Japan, Mongolia and the Philippines mention that their national genebanks store safety duplicates from other genebanks. Tajikistan reports that it has safety duplicated germplasm accessions in the genebank of VIR. Japan reports that it regards the inclusion of accessions in both medium-term and in long-term storage as a form of safety duplication. Armenia and Nepal mention that they have very low levels of safety duplication, especially for vegetables and grain-legume species. Malaysia reports that it has no monitoring of safety duplication in place. Myanmar indicates that it recognizes the need for safety duplication at a safer genebank.

Europe
Fifteen European countries reported on aspects of safety duplication. Albania mentions that it has a very low level of safety duplication. Belarus reports safety duplication of accessions of the respective mandate crops at CGIAR centres. Czechia mentions that it duplicates its accessions in Slovakia and at SGSV. Estonia reports that it still needs to resolve its safety duplication of fruit trees and *in vitro* materials. Finland reports that it has started to develop a safety collection network for its national PGRFA collections and for valuable private collections. France reports that it duplicates materials under the auspices of a cooperation network. Germany mentions that it has duplicated 36 percent of its accessions at SGSV and that its field genebank accessions are backed up through cryopreservation. The Republic of Moldova indicates that it has no safety duplication of its collections in place. The Nordic countries and Switzerland report that they keep their national field genebank collections in at least two sites within each respective country. Poland mentions that it is in the process of establishing its national base collection and that it is simultaneously arranging for the safety duplication of this collection. Portugal indicates that it regards the storage of medium-term storage accessions in long-term storage as a form of safety duplication and that it is testing the cryopreservation of vegetatively propagated plants. Romania reports that it has started safety duplicating its field genebank collections *in vitro*. Serbia reports that it stores duplicates of accessions at its national genebank. Sweden reports that it has significantly increased its clonal archives for the duplication of field genebank accessions. The United Kingdom reports that it uses cryopreservation for safety duplication of fruit trees and wild taxa.

3.5.2 Situation in the international and regional genebanks

The status of safety duplication of the mandated crops maintained by the CGIAR genebanks and WorldVeg is presented in Table 3.27.

NordGen reports that 26 756 of its accessions (80 percent of its entire holdings) are safety duplicated; 50 percent of its total holdings are in long-term seed storage at the Department of Food Sciences at Aarhus University, Denmark, and 74 percent are in black-box storage at SGSV. The duplicated accessions include 170 genera and 345 species; 18 percent of all the duplicated accessions are wild populations, 13 percent are

FV/LR, 15 percent are advanced cultivars and 51 percent are research materials.

CATIE reports that about 1 361of its accessions, or 22 percent of its total seed holdings, are safety duplicated. This includes 959 accessions stored at SGSV. The remaining accessions are in long-term seed storage at WorldVeg. The duplicated accessions include 19 genera and 40 species; 5 percent are samples of wild populations, and 95 percent are FV/LR.

TABLE 3.27
Safety-duplication levels of the CGIAR and WorldVeg crop collections in 2022

Centre	Crop	Safety duplication (%)	Safety duplication at SGSV (%)
AfricaRice	Rice	85	85
Bioversity International	*Musa* (banana)	73	
CIAT	Pulses	98	97
	Forages	91	91
	Cassava	62	
CIMMYT	Maize	89	82
	Wheat	74	72
	Triticale	91	90
	Barley	57	57
CIP	Potato	92	70
	Sweet potato	90	26
	Andean root and tuber crops	79	20
ICARDA	Barley	96	95
	Wheat	88	82
	Chickpea	81	64
	Lentil	77	64
	Broad bean	65	28
	Grass pea	90	80
	Forage and range species	70	34
ICRAF	Multipurpose trees	20	9
ICRISAT	Finger millet	97	86
	Groundnut	67	65
	Kodo millet	99	98
	Pearl millet	80	76
	Pigeonpea	96	95
	Sorghum	88	82
IITA	*Musa* (banana and plantain)*	30	
	Cassava*	50	
	Cowpea	94	94
	Maize*	51	32
	Yam*	35	
	Legumes	92	92
ILRI	Forages	67	31
IRRI	Rice	92	92
WorldVeg	Vegetable crops	63	59

Notes: *Safety duplication as of December 2019 (direct communication); safety duplication at Svalbard Global Seed Vault (SGSV) as of December 2022 (SDG 2.5.1.a report).

SPGRC serves as a long-term seed storage backup for the national holdings of SADC countries. It reports that 60 percent of its total germplasm holding, constituted almost entirely of FV/LR of 19 genera and 23 species of staple food crops, is also under black-box conservation at SGSV.

3.5.3 Summary assessment

Safety duplication of *ex situ* conserved accessions is an essential part of genebank management. It is clear from the narrative reports that the importance of safety duplication is well understood and recognized. This is also evident from the increasing number of countries (63 in 2022 versus 13 in 2009) that have deposited accessions at SGSV. Despite these gains, many genebanks still have no, or only have limited, safety duplication. Many genebanks have difficulties regenerating or multiplying their collections adequately. They store accessions in the form of low numbers of seeds or plants and consequently do not have the materials needed to safety duplicate them. In other genebanks, materials are duplicated between active and base collections or between field genebanks and in vitro genebanks – and are thus regarded as safety duplicated. Overall, the reported safety duplication figures are low, particularly in national and regional genebanks, and more so for vegetatively propagated species, a situation that clearly indicates the need to accord more attention and higher priority to safety duplication.

SGSV is playing an important role in the backup safety duplication of seed collections. The numbers are impressive, both in terms of the quantity of samples deposited and in terms of their diversity. While SGSV is providing this important service for orthodox seed collections, no similar mechanism yet exists for species that produce recalcitrant seeds or propagate vegetatively, and germplasm from these groups is, therefore, particularly at risk of being poorly safety duplicated.

3.6 Germplasm health

Germplasm-health issues are becoming increasingly important in the conservation, distribution and use of PGRFA. The increased movement of germplasm within and between countries and continents increases the potential spread of pests and diseases. In response, a number of efforts have been made to minimize and mitigate such problems, especially via improvements to phytosanitary and plant-quarantine measures. Box 3.4 describes some of the activities carried out by CGIAR germplasm health units (GHUs).

3.6.1 Situation in the regions

Sub-Saharan Africa

Eritrea, Ethiopia, Kenya and Nigeria report a lack of the technical facilities and trained personnel needed to conduct the health tests and other activities required for germplasm distribution. Madagascar mentions problems with pests and diseases in its field genebank collections. Namibia reports that it has insufficient capacity to identify and manage storage pests and diseases.

Latin America and the Caribbean

Chile mentions the need to determine the phytosanitary status of regenerated material before proceeding with its long-term conservation and distribution. Colombia and Costa Rica report that germplasm health activities are part of their overall germplasm management efforts. Cuba and Ecuador report that establishing pathogen-free collections is a high priority.

Asia and Oceania

Azerbaijan reports that it uses molecular techniques to monitor germplasm health. Japan indicates that it applies stringent plant quarantine regulations to protect itself against the introduction of pests and diseases and that this impedes regional collaboration and the introduction of breeding materials from abroad. Malaysia mentions problems with pests and diseases during regeneration activities. Papua New Guinea reports that a recent outbreak of a

Box 3.4

Implementation of germplasm health activities in CGIAR genebanks to promote safe global germplasm exchange and prevent the transboundary spread of pests

The germplasm health units (GHUs) of the CGIAR use comprehensive phytosanitary testing procedures to assess the heath of accessions and hence their suitability for safe conservation or distribution (Kumar *et al.*, 2021). The GHUs pursue six strategic objectives: (i) to ensure that the transboundary movement of germplasm and non-seed biological materials complies with the regulatory guidelines of the importing and exporting countries and that the materials are free from quarantine pests; (ii) to develop and adopt phytosanitary procedures that generate pest-free germplasm; (iii) to develop diagnostic tools for seed-health monitoring and pest surveillance; (iv) to conduct pest-risk assessments of germplasm activities, including conservation, seed increase and transfers; (v) to contribute to the development of phytosanitary capacity around the globe; and (vi) to organize a GHU community of practice that forms a network of centres for transboundary pest prevention.

The GHUs closely collaborate with national and regional plant-quarantine organizations to export and distribute germplasm samples to partners. Between 2012 and 2020, they tested 538 053 accessions for pests and diseases, and cleaned 102 593 accessions (CGIAR Genebank Platform, 2024a). They applied uniform standards to all seed exports and imports to ensure pest-free germplasm transfers. In 2018 and 2019, GHUs facilitated 1 300 germplasm transfers from genebanks and 2 600 from breeding programmes to a total of 150 countries. In 2018 and 2019, extensive testing resulted in the detection and rejection of 7 percent of 335 928 genebank samples and 3 percent of 118 044 breeding samples.

The GHUs use new technologies that allow more accurate and rapid detection of existing and newly diagnosed pests. They strive to maintain a balance in terms of adopting technologies that offer the best cost and time efficiency, meet regulatory requirements and comply with ISO quality-management systems. However, specific phytosanitary standards for the international exchange of germplasm have not been developed, and requirements for germplasm shipments often vary from country to country. To help ensure phytosanitary compliance, GHUs have begun developing the CGIAR GreenPass Phytosanitary Protocol (GreenPass) (CGIAR Genebank Platform, 2024b). The protocol will detail best procedures to follow in germplasm regeneration and health assurance while maintaining transparency in risk assessment and mitigation strategies. The intention is for the initiative to allow national plant protection officers to expedite the clearance of plant germplasm material originating from GreenPass-accredited facilities by eliminating redundant checks or reducing the processing time for material received from accredited facilities.

Sources: CGIAR Genebank Platform. 2024a. Genebank operations. Summary. 2012-2021. In: *CGIAR Genebank Platform*. [Cited 23 October 2024]. https://www.genebanks.org/resources/genebanks-in-numbers/genebank-operations-data/; CGIAR Genebank Platform. 2024b. GreenPass puts germplasm distribution in the fast lane. In: *CGIAR Genebank Platform*. [Cited 23 October 2024]. https://www.genebanks.org/news-activities/news/greenpass/; Kumar, P.L., Cuervo, M., Kreuze, J.F., Muller, G., Kulkarni, G., Kumari, S.G., Massart, S. *et al.* 2021. Phytosanitary interventions for safe global germplasm exchange and the prevention of transboundary pest spread: the role of CGIAR germplasm health units. *Plants (Basel)*,10(2): 328. https://doi.org/10.3390/plants10020328.

new coconut disease is threatening the regional coconut collection.

Europe

France reports that the transition to more agroecological practices at experimental stations has made regeneration work more complex, especially in terms of pest management. Germany reports that targeted efforts are being made to identify viruses in national fruit accessions and where applicable to eliminate them and maintain pathogen-free accessions. Such procedures are also required by AEGIS (A European Genebank Integrated System for PGRFA) for the inclusion of accessions in the European Collection.[52]

[52] Further information at https://www.ecpgr.org/aegis/european-collection/european-collection

Virus-infected grapevine accessions are a significant problem, as no techniques for curing infected plants are available. Quarantine issues mean that in the European Union access to grapevine germplasm from elsewhere is limited. Norway reports regular monitoring of the health of accessions in its clonal collection and that issues have been reported for several fruit-crop collections, including the appearance of two diseases in the apple and pear field collections. Romania indicates an interest in strengthening regional and international collaboration on germplasm health, possibly on a cost-sharing basis.

3.6.2 Situation in the international and regional genebanks

CePaCT has established a health-testing unit to support the safe exchange of crop and tree germplasm, and it carries out research on plant-pathogen diagnostics. It plans to provide diagnostic services to the Pacific region. Similar germplasm-health testing procedures are in place at WorldVeg.

All 11 CGIAR genebanks have well-functioning GHUs that use a multidisciplinary approach to ensure phytosanitary protection that allows the safe conservation and global movement of germplasm and breeding lines for agricultural research and food security (see Box 3.4). To promote capacity development in diagnostics, seed-health testing and seed treatment, the CGIAR GHUs organize at least ten workshops each year for staff from national and regional organizations.

3.6.3 Summary assessment

The impact of germplasm-health issues on the management and distribution of materials increased overall during the reporting period. This is particularly the case for the CGIAR centres. However, several national genebanks do not have the human and/or technical capacity to address germplasm-health issues adequately and ensure the availability and exchange of disease-free germplasm. There is an obvious need to build such capacities, including through staff training. Regional cooperation, especially on infrastructure development and the sharing of specialized knowledge, would greatly facilitate this process.

3.7 Characterization for *ex situ* conservation

Characterization is a key activity in genebank management. Characterization procedures based on standardized and calibrated measuring formats and categories ideally follow internationally agreed descriptor lists. A wide range of crop-descriptor lists have been developed, including by Bioversity International (CGIAR, 2024), the International Union for the Protection of New Varieties of Plants (UPOV, 2011) and the National Plant Germplasm System (NPGS) of the United States (USDA-ARS, 2022). Bioversity International has also published Guidelines for developing crop descriptor lists (Bioversity International, 2007). The use of molecular characterization is becoming more widespread because the technologies required are increasingly affordable and opportunities for outsourcing within countries and for international collaboration are becoming more mainstream. Characterization is discussed further in Chapter 4.

3.7.1 Situation in the regions

Sub-Saharan Africa

Guinea reports that collecting yam, rice and groundnut is followed by on-station characterization. Madagascar reports the characterization of well-performing clones and their testing for disease resistance. Uganda reports that the national genebank lacks the permanent nursery and screen houses needed for characterization activities.

Northern Africa

Egypt reports that it has characterized collected germplasm materials with the objective of integrating them into breeding programmes.

Latin America and the Caribbean

Guyana reports that outstanding progress has been made in the extensive characterization of more than 65 cassava landrace varieties.

Asia

Kyrgyzstan reports that it characterized 100 wheat varieties as part of a multiplication project. Türkiye mentions that the characterization of its germplasm collections is a major priority. Yemen reports that it lacks the staff to characterize its collections.

Europe

Czechia reports that a large proportion of its national collection has been characterized. Finland reports that it has characterized its national apple collection using morphological, phenological and genetic analyses. France mentions that 16 cooperation networks are responsible for the characterization of its PGRFA collections. Norway reports that many of the PGRFA conserved in its *ex situ* collections have not been adequately characterized and identified, and that these activities will be given due priority in future. Spain reports that it has had difficulties assessing the state of characterization activities, as different institutions responded to the first and second national surveys and the overall response rate was low.

3.7.2 Situation in the international and regional genebanks

The CGIAR genebanks report that at the end of 2020 a total of 721 578 accessions (88 percent of their total holdings) had passport and characterization data available online (CGIAR Genebank Platform, 2022). Based on separate reports to FAO from ten CGIAR centres and WorldVeg, just under 1.5 million accessions were characterized for an overall average of 20 traits during the reporting period. In addition to morphological characterization, these ten CGIAR centres report that 128 712 accessions have associated sequence data. Overall, the centres report 508 publications on characterization in refereed journals and 179 in non-refereed journals between 2012 and 2019. A further 308 publications were produced by germplasm recipients.

NordGen reports that 3 859 accessions, including 13 species representing six genera *(Brassica, Daucus, Hordeum, Pisum, Trifolium* and *Vicia*), were characterized for a range of between 2 and 22 morphological traits. In addition, morphological and molecular data were used to assess diversity (Solberg and Yndgaard, 2015; Geoffriau *et al*., 2018) and support genebank management (Solberg, Yndgaard and Palmé, 2017; Solberg *et al*., 2018; Yndgaard *et al*., 2016).

3.7.3 Summary assessment

Some countries report progress in the characterization of their collections. However, the germplasm collections of many national genebanks have still not been comprehensively characterized. It appears from the country reports that international descriptors are used sporadically. At the international level, the CGIAR genebanks have characterization data for most of their collections. NordGen was the only regional centre to provide information on characterization efforts. It reports that characterization data have been used to assess the diversity of collections as well as to enhance genebank management.

3.8 Regeneration

Regeneration of accessions to address low viability and/or decreased inventory requires good planning and resources and is among the most complex and difficult routine activities undertaken by genebanks. The frequency of regeneration depends on the conservation method as well as the type and quality of the material conserved. Genebanks aim to maintain the genetic integrity of accessions during regeneration by taking sample size into account and ensuring careful handling throughout the process. Determining the priority of the accessions to be regenerated requires routine viability and stock monitoring, and a functional information management system.

TABLE 3.28
Regeneration activities between 2012 and 2019 and regeneration status at the end of 2019, by region

Region (number of reporting countries)	Accession holdings	Accessions regenerated (%)	Accessions in need of regeneration (%)	Accessions in need of regeneration with no budget (% of accessions in need of regeneration)	Accessions in need of regeneration with no budget (% of accession holdings)
Northern Africa (5)	64 454	71	45	50	22
Sub-Saharan Africa (20)	169 610	25	42	63	27
Northern America (1)	110 363	-	30	67	20
Latin America and the Caribbean (15)	328 356	56	39	60	24
Asia (20)	898 859	26	17	30	5
Europe (22)	760 873	36	20	58	12
Oceania (2)	91 719	6	27	94	25
Total (85)	**2 424 234**	**32**	**24**	**54**	**13**

Over the 2012 to 2019 period, 85 countries regenerated a total of 780 375 accessions (or 32 percent of all the 2 424 234 accessions reported). The countries with the highest reported number of regenerated accessions were Germany (111 479, or 65 percent of the total), Brazil (98 825, or 59 percent), India (59 139, or 14 percent), France (40 599, or 39 percent) and Bangladesh (34 110, or 127 percent). Thirty-one countries[53] report severe and/or specific difficulties with their regeneration activities, especially in the case of CWR and vegetatively propagated crops, and several report considerable backlogs.

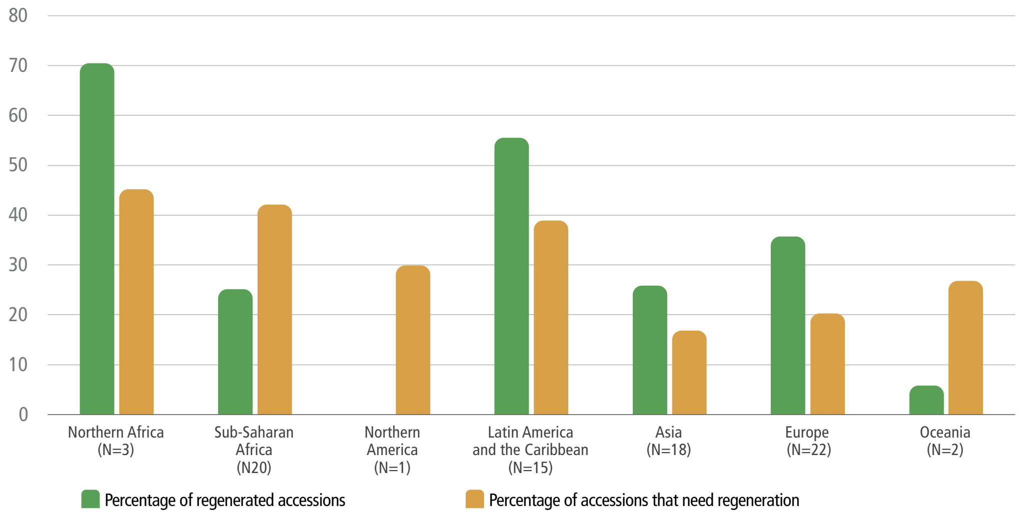
A regional comparison (Table 3.28 and Figure 3.7) indicates that Northern Africa had the highest percentage of regenerated accessions (71 percent), followed by Latin America and the Caribbean (56 percent), Europe (36 percent), Asia (26 percent), sub-Saharan Africa (25 percent) and Oceania (6 percent).

Almost 600 000 accessions (24 percent) are in need of regeneration. Northern Africa (45 percent), sub-Saharan Africa (42 percent) and Latin America and the Caribbean (39 percent) are the regions with the highest percentage of accessions needing regeneration. All regions report insufficient funds to regenerate all the accessions requiring regeneration. Oceania reports insufficient funds to regenerate 94 percent of the accessions requiring regeneration (25 percent of total germplasm holdings). The equivalent figures for other regions were: 67 percent (20 percent of total holdings) in Northern America; 63 percent (27 percent of total holdings) in sub-Saharan Africa; 60 percent (4 percent of total holdings) in Latin America; and 58 percent (12 percent of total holdings) in Europe.

Table 3.29 summarizes regeneration activities and results for the period 2012 to 2019 by crop group. At the global scale, cereals are the crop group for which the largest number of accessions were regenerated (27 percent of total cereals holdings as of 2019), followed by pulses (33 percent), oil plants (51 percent), vegetables (32 percent) and roots and tubers (155 percent). Cereals (21 percent of total holdings), pulses (31 percent) and vegetables (28 percent) are also the groups that have the most accessions requiring regeneration. With the exception of oil plants, these are the three crop groups that

[53] Albania, Argentina, Armenia, Azerbaijan, Brazil, Colombia, Egypt, Eritrea, Ethiopia, Ghana, Indonesia, Kenya, Madagascar, Mexico, Mongolia, Myanmar, Namibia, Nepal, Niger, Philippines, Republic of Moldova, Spain, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Uruguay, Yemen, Zambia, Zimbabwe.

FIGURE 3.7
Percentages of regenerated accessions and accessions in need of regeneration, by region



Note: N indicates the number of reporting countries.

have the largest number of accessions in national genebanks overall. The other crop groups with high a percentage of overall accessions requiring regeneration are nuts (42 percent), fibre plants (41 percent), material plants (40 percent), forages (36 percent), stimulants (31 percent), medicinal plants (31 percent) and ornamentals (28 percent).

3.8.1 Situation in the regions

Sub-Saharan Africa

Fifteen sub-Saharan African countries report difficulties with regeneration activities. Constraints included those related to a lack of human resources capacity (Botswana, Kenya, Mali, Uganda and Zimbabwe), lack of infrastructure (Eritrea, Zimbabwe), difficulties with specific crops or type of crops (Kenya, Nigeria, the Sudan and Uganda), lack of knowledge (Uganda), ecological problems (Botswana), lack of financial resources (Madagascar and Mali), lack of an adequate documentation system (Togo and Uganda) and difficulties keeping up with regeneration needs because of longevity being affected by a lack of a reliable electricity supply (Zambia). Ethiopia reports that it significantly increased regeneration over the reporting period. South Africa mentions the involvement of farmers in regeneration activities.

Northern Africa

Egypt and Tunisia report a lack of financial and human resources, especially for the regeneration of cross-pollinating crops.

Latin America and the Caribbean

Eleven countries provided information on regeneration activities. A number of constraints are mentioned, including limited financial resources (Argentina, Brazil, Cuba and Mexico), problems with cross-pollinated species and perennial crops such as coconut (Brazil, Cuba and Guatemala), the need to improve infrastructure (Colombia) and the lack of a monitoring system for seed viability and inventory that can flag accessions requiring regeneration (Peru). Costa Rica, Guatemala, Mexico and Uruguay report

TABLE 3.29

Number and percentage of accessions regenerated between 2012 and 2019 and requiring regeneration as of 2019, by crop group

Crop group	Number of accessions in national genebanks (2019)	Number of accessions regenerated	Percentage of accessions regenerated	Number of accessions requiring regeneration	Percentage of accessions requiring regeneration
Cereals	1 059 780	281 715	26.6	223 060	21
Pulses	301 299	97 815	32.5	93 180	31
Oil plants	158 618	80 152	50.5	13 329	8
Vegetables	246 672	79 625	32.3	69 098	28
Roots and tubers	44 286	68 492	154.7	9 408	21
Fruit plants	72 620	35 919	49.5	18 624	26
Fibre plants	66 626	31 326	47	27 129	41
Forages	169 921	19 296	11.4	61 160	36
Medicinal plants	27 519	13 742	49.9	8 191	30
Sugar crops	9 343	8 910	95.4	479	5
Stimulants	15 909	7 736	48.6	4 846	31
Pseudo-cereals	14 765	5 534	37.5	2 740	19
Ornamentals	20 952	4 981	23.8	5 538	26
Herbs and spices	18 243	4 836	26.5	4 104	23
Nuts	3 494	1 617	46.3	1 464	42
Material plants	6 371	1 268	19.9	2 516	40
Other	187 816	37 411	19.9	47 710	25
Total	**2 424 234**	**780 375**	**32.2**	**592 576**	**24**

Note: Data provided by 85 countries.

backlogs in their regeneration efforts. Chile reports prioritizing the regeneration of food crops that are of interest to plant-breeding programmes. Colombia mentions the need to develop more economical protocols for species that require special regeneration conditions. Trinidad and Tobago mentions that it cultivates its accessions annually and suffers significant losses. Ecuador reports the use of the monitoring system CARDEX to identify accessions with low inventory and/or low viability. Guatemala reports the regeneration of part of its bean collection through the Mesoamerican Network on Plant Genetic Resources (REMERFI) with financial assistance from the Crop Trust. Guyana reports significant improvements in its regeneration activities.

Asia

Nineteen Asian countries provided information on regeneration. Philippines reports a lack of viability monitoring in many of its genebanks and that it uses the quantity of seed and the initial storage date as criteria for setting priorities. Four countries (Bangladesh, Japan, Türkiye and Uzbekistan) report well-functioning regeneration activities. Azerbaijan reports the rejuvenation of old fruit and nut trees. Japan reports an operational cooperative project with the private sector for the regeneration of problematic vegetable species. Jordan and Lebanon report that they carry out regeneration in collaboration with other genebanks.

Constraints to successful regeneration are reported by a number of countries and included the following: lack of adequate funding (Armenia); lack of a functional database-management system (Armenia); problems with specific groups of crops and species such as CWR and cross-pollinated species (Azerbaijan and Myanmar); limited capacity (Indonesia and Kyrgyzstan); lack of adequate facilities (Malaysia, Myanmar and Tajikistan); and the need for more ecologically diverse regeneration sites (Mongolia, Nepal and Tajikistan). Yemen reports that it has not been able to conduct viability tests or regenerate materials since the start of the war in 2013.

Oceania

Papua New Guinea reports that it replants its annual vegetatively propagated crops regularly, at least once a year.

Europe

Albania reports that approximately half its accessions are cross-pollinated and have never been regenerated. Czechia mentions that as part of its GRIN-Global Czech documentation system, it has installed a new automatic system for monitoring seed inventory and viability to identify accessions needing regeneration. France mentions that it operates a complex network that does not have funds for regeneration. Belarus reports a lack of specific guidelines and experience for the regeneration of CWR. Germany reports that the average rate of regeneration of its fruit-tree accessions is currently 75 percent, that CWR accessions have not been regenerated or multiplied and that its grapevine collection is continuously replanted in segments, as viability and health status are checked annually.

The Kingdom of the Netherlands reports that over the whole reporting period approximately 80 percent of CGN's regenerations were done by the centre itself but that from 2016 onwards, when seed companies became actively involved in the regeneration of CGN accessions, only about 43 percent of the regenerations were carried out by CGN. The regenerations are usually caried out in the Kingdom of the Netherlands but in some cases are done in other countries, such as France, Spain, Slovakia or Morocco. Poland reports that some orphan crops have no curator assigned to them to coordinate regeneration, storage or maintenance. Portugal reports challenges related to cross-pollinated species, in particular to the special infrastructural requirements associated with these species.

Romania reports that young scientists have been assigned the role of specializing in the regeneration/multiplication of individual crops or crop groups and that, accordingly, partnerships with vegetable research institutes have been established. Switzerland mentions that for some crop groups (e.g. fruit accessions maintained in field genebanks), regeneration is organized by a national coordinator.

3.8.2 Situation in the international and regional genebanks

Regeneration/multiplication activities at the CGIAR centres during the period between 2012 and 2020, as reported by the CGIAR Genebank Platform, are summarized in Table 3.30. The CGIAR genebanks have a multiplication rate that is almost four times the rate of regeneration, illustrating that the level of distribution is high and that viability is relatively stable overall, at least for accessions that are in high demand. Separate reports to FAO by 11 CGIAR centres and WorldVeg indicate that more than 900 000 accessions were regenerated during the entire reporting period. At the end of 2019, just under 180 000 accessions needed regeneration, and the budget to regenerate just over 28 500 accessions was lacking.

NordGen reports the development of a strategy for mitigating the challenge posed by increasing regeneration backlogs. A total of 5 568 accessions were regenerated over the reporting period (17 percent of the total holdings), including accessions from 69 genera and 224 species. The number of accessions needing regeneration at the end of the reporting period totalled 4 391 (14 percent), including accessions from 139 genera and 276 species. The budget to regenerate 2 110 accessions (7 percent) was lacking.

3.8.3 Summary assessment

Although more than 32 percent of accessions in national holdings are reported to have been regenerated over the reporting period, regeneration remains one of the main challenges for many countries and genebanks. Technical constraints, lack of properly trained staff, insufficient funding and poor infrastructure are reported. Regeneration of CWR and out-crossing species are problematic for many genebanks. Many are unable to monitor viability and inventory adequately and are thus unable to prioritize effectively. This is a significant constraint given the wide array of crop groups represented in national collections. Many of these groups require specialized regeneration techniques or (because of a lack of research or lack of interest from users) are assigned low priority by genebanks, especially in terms of the allocation of already-limited budgets. Additionally, very limited cooperation at regional or global levels, including cooperation involving regional and international genebanks, is reported. Collaboration with private breeding companies with solid technical knowledge is mentioned by a few countries.

3.9 Documentation

Documentation is an essential aspect of genebank management. A unique and permanent accession identifier for each conserved accession at a given genebank is a key element of proper documentation. DOIs (FAO, 2021) provide an opportunity to link accession/germplasm information in different publications and across different information systems.

A genebank should manage all the data and information generated relating to all aspects of the conservation and use of the germplasm it preserves, including passport (Alercia, Diulgheroff and Mackay, 2015; Alercia *et al*., 2020), characterization, evaluation, inventory and collection-management data and metadata. The use of a genebank information management system is the most efficient and effective means of managing such data. If possible, the system should include built-in automated tools for checking inventory and viability and flagging accessions requiring regeneration. Recent years have seen the development of a number of systems, including the German Genebank Information System (GBIS) (GBIS/I, 2022) and Alelo, developed by Embrapa in

TABLE 3.30

CGIAR regeneration and multiplication operations, 2012 to 2020

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of accessions regenerated	15 815	12 670	16 674	11 641	25 290	19 023	21 220	15 193	11 414
Number of accessions multiplied	54 153	45 425	56 804	58 168	74 873	72 612	85 594	75 799	68 616
Total number of accessions	710 001	725 244	738 215	750 604	757 767	768 576	773 402	760 467	736 210
Number of accessions immediately available	465 358	492 654	525 410	559 053	580 706	608 751	621 915	592 118	601 811
Percentage of accessions available	66	68	71	74	77	79	80	78	82

Source: CGIAR Genebank Platform. 2022. Genebank operations. In: *CGIAR Genebank Platform*. [Cited 4 June 2022]. https://www.genebanks.org/resources/genebanks-in-numbers/genebank-operations-data/

Brazil (Embrapa, 2022). Regional systems include the Nordic Baltic Genebanks Information System (GeNBIS) (GeNBIS, 2022), the SADC Plant Genetic Resources Documentation System (SDIS) (SADC, 2022) and EURISCO (ECP/GR, 2022).

At the global level, GRIN-Global was developed by the United States Department of Agriculture – Agricultural Research Service, the Crop Trust and Bioversity International to enable genebanks to store, manage and publish information associated with PGRFA; the system is freely available (GRIN-Global, 2022). The recent development of GG-CE, which builds on GRIN-Global and addresses some gaps in functionality, presents a major opportunity for genebanks to adopt a free-access, easy-to-use system (Crop Trust, 2022a). Expert system technologies, which are becoming increasingly accessible, could soon be used to oversee and guide the whole germplasm management process and greatly facilitate the curation and use of *ex situ* collections.

Genesys is an international global portal managed by the Crop Trust that allows accession data to be shared and facilitates the ordering of germplasm (Crop Trust, 2022b). It includes accession-level passport, characterization and evaluation data as well as ecogeographical information associated with accession collecting sites. Institutions can also utilize Embedded Genesys, an addition that allows the integration of their genebank accession data with their institutional/corporate websites (Crop Trust, 2020). Another option for making the passport data of genebank accessions publicly available is WIEWS (FAO, 2024b), which serves as the data repository for the plant indicator of SDG Target 2.5 (United Nations, 2022) and stores and publishes accession-level passport data for the largest global inventory of *ex situ* collections. Finally, the International Treaty's Global Information System for PGRFA (GLIS) integrates and augments existing systems, creating a global entry point for access to information and knowledge related to capacity development for PGRFA conservation, management and utilization (FAO, 2023c).

3.9.1 Situation in the regions

Northern Africa

At the time of reporting, Tunisia was in the process of fully adopting GG-CE.

Sub-Saharan Africa

The information provided from this region indicates that three countries (Eritrea, the Niger and the United Republic of Tanzania) had an independent documentation system at the time of reporting. Five countries (Botswana, South Africa, the United Republic of Tanzania, Zambia and Zimbabwe) were using SDIS. Ethiopia, Ghana, Kenya, Nigeria and Zambia were in the process of adopting GG-CE. Six country reports (Guinea, Madagascar, Mali, Namibia, Togo and Uganda) mention the need to adopt a documentation system. Several countries mention problems with the systems that were being used at the time.

Latin America and the Caribbean

The information provided from this region indicates that three countries (Brazil, Mexico and Peru) had an independent documentation system at the time of reporting. The Plurinational State of Bolivia, Chile and Uruguay were using GRIN-Global, and Ecuador and Mexico were in the process of adopting it. Argentina and Colombia were in the process of adopting GG-CE. Three country reports (Costa Rica, Cuba and Guatemala) refer to the need to install a national documentation system.

Northern America

Canada and the United States were using GRIN-Global at the time of reporting.

Asia

The submissions from Asia indicate that four countries from the region (Indonesia, Malaysia, the Philippines and Türkiye) had an independent documentation system at the time of reporting. Four countries (Jordan, Lebanon, Oman and Pakistan) were using GRIN-Global. Armenia had plans to install this system, and Azerbaijan and Viet Nam were evaluating it. Two countries

(Armenia and Azerbaijan) were regularly updating their data in EURISCO as members of ECPGR. Uzbekistan was planning to collaborate with EURISCO. Five country reports (Bangladesh, Mongolia, Nepal, Uzbekistan and Yemen) mention the need for a functional documentation system.

Europe
According to the submissions from Europe, three countries (France, the Republic of Moldova and Romania) had independent documentation systems at the time of reporting. Denmark, Finland and Norway were using GeNBIS. Czechia was using GRIN-Global. Portugal had a system that was supported by GRIN-Global. The United Kingdom used GG-CE, and Belarus was planning to install GRIN-Global. Seven countries (Belarus, France, the Kingdom of the Netherlands, Romania, Serbia, Switzerland and the United Kingdom) report regularly publishing national data through EURISCO. The report from Serbia mentions the need to install a proper documentation system such as GRIN-Global.

Oceania
Australia was using GRIN Global at the time of reporting and New Zealand was in the process of evaluating it. Papua New Guinea reported the need for a functional documentation system.

3.9.2 Situation in the international and regional centres

Bioversity International, CIMMYT, CIAT, CIP and WorldVeg had adopted GG-CE at the time of reporting. AfricaRice, IRRI, ILRI, IITA and ICARDA were in the process of adopting it, while ICBA, ICRAF and ICRISAT were evaluating it. As of May 2019, GLIS reported that more than 834 000 accessions have DOIs assigned, with the CGIAR centres accounting for approximately 94 percent of the total (CGIAR Genebank Platform, 2019).

Among regional centres, CATIE was using its own databases for its seed and field collections. CePaCT was using its own genebank documentation and information system (PACGEN) but was in discussions about adopting GG-CE. NordGen was using GeNBIS, a customized version of GRIN-Global. SPGRC was using SDIS. At the end of 2021, 12 927 accessions from regional genebanks had been assigned DOIs.

3.9.3 Summary assessment

Despite being regarded as a crucial aspect of genebank management for many years and receiving support from the international community, progress in the area of documentation has been rather limited. Many countries still struggle to document passport and other genebank management data. The recent development of GG-CE and technical support provided by the Crop Trust may encourage national genebanks to adopt it. Encouragingly, the CGIAR and other international centre genebanks, as well as the majority of regional centres, are either using or in the process of adopting GG-CE. The increasing use of DOIs improves not only collection management but also the capacity to refer to specific germplasm in published papers and breeding pedigrees. The availability of web portals such as EURISCO, Genesys and WIEWS allows the global community to know what germplasm is conserved in which genebank collections. The option of using Embedded Genesys makes it possible for institutes to provide their genebank inventories on their institution websites without the need to develop their own interfaces.

3.10 The Multilateral System

In accordance with Article 11.2 of the International Treaty, the International Treaty's Governing Body periodically invites Contracting Parties to report on the PGRFA under their management and control that are in the public domain and are in the MLS. A summary of the materials from national, regional and international genebanks placed under the MLS is presented in Table 3.31. As of 31 December 2021, materials under the MLS totalled over 2.3 million accessions, as reported by 76 Contracting Parties and 15 regional and international centres (Article 15 bodies).[54] This does not include 23 249 accessions from six countries that are not Contracting Parties but have nonetheless included part of their collections in the MLS.[55]

The MLS materials of the Contracting Parties and Article 15 bodies account for about 54 percent of their total *ex situ* holdings as reported for SDG Indicator 2.5.1.a. While there is scope for improving the national average of 43 percent over time, it is noteworthy that about one-third of Contracting Parties have over 70 percent of their collections under the MLS. As might be expected, given that they mainly cover Annex 1 crops,[56] the international centres and regional centres have almost their entire collections available under the MLS.

3.11 Germplasm movement (distribution/exchange)

3.11.1 Global germplasm exchange

A thematic study on global germplasm exchange (Khoury *et al.*, forthcoming) was undertaken based on an analysis of two complementary information sources – WIEWS and the Data Store of the MLS – covering the period 2012 to 2019 in both cases. The WIEWS datasets primarily related to distributions of germplasm from national genebanks. Provider countries, provider institutions, types of recipient (optionally), crops and total numbers of accessions and samples distributed were reported for two periods (2012 to 2014 and 2014 to 2019). The International Treaty data included all distributions made under the Standard Material Transfer Agreement (SMTA) reported to the International Treaty's Governing Body, and included distributions made by genebanks and by breeding programmes and other types of organization. The data primarily referred to distributions made by CGIAR genebanks and breeding programmes and included information on countries where providers and recipients were located, crop names and numbers of samples distributed between 2012 and 2019.

According to the WIEWS dataset, national genebanks in 87 countries distributed 1 269 818 accessions (an average of approximately 159 000 per year) and 4 182 582 million samples (about 523 000 per year) between 2012 and 2019, with well over 90 percent of distributions made within the respective country. Approximately 70 percent of accessions and 86 percent of samples were distributed by providers located in countries that were Contracting Parties to the International Treaty, while 37 percent of accessions and 36 percent of samples were distributed by providers located in countries that were Contracting Parties to the Nagoya Protocol. The main recipients included national agricultural research centres (NARCs), followed by farmers, NGOs and the private sector. The International Treaty data covered the distribution of more than 3.9 million samples (approximately 497 000 per year) from genebanks, breeding programmes and other organizational types using the SMTA. The germplasm distribution pattern differs from that indicated by the WIEWS data, with three-quarters (77 percent) of distributions occurring across international borders and only one-quarter (24 percent) occurring within individual countries. The number of such distributions is considerably higher than the equivalent numbers documented in the SoW1 and the SoW2.

Approximately 56 percent of all distributed accessions and 38 percent of distributed samples reported in the WIEWS dataset were of crops listed in Annex 1 of the International Treaty. The non-Annex 1 crops comprising the other 44 percent of accessions distributed were soybean, cotton,

[54] Article 15 Bodies are international agricultural research centres of the CGIAR and other international institutions with *ex situ* collections of PGRFA placed under the MLS of the Treaty.

[55] Azerbaijan (8 386 accessions placed under the MLS), Belarus (6), Bosnia and Herzegovina (6), Tajikistan (3 782), Uzbekistan (189), Viet Nam (10 880).

[56] International Treaty on Plant Genetic Resources for Food and Agriculture, Annex I, List of crops covered under the Multilateral System.

TABLE 3.31

Number of accessions conserved *ex situ* and percentage placed under the Multilateral System, by region and subregion

Regions and subregions (number of countries or genebanks)	Number of accessions		Percentage
	Genebanks	MLS	
Northern Africa (4)	128 046	34 131	27
Northern Africa (4)	128 046	34 131	27
Sub-Saharan Africa (13)	176 673	103 745	59
Eastern Africa (7)	153 506	95 663	62
Western Africa (6)	10 517	8 082	77
Northern America (2)	705 699	585 029	83
Northern America (2)	705 699	585 029	83
Latin America and the Caribbean (8)	306 118	30 742	10
Central America (3)	3 945	619	16
South America (5)	295 076	30 123	10
Oceania (2)	300 138	111 636	37
Melanesia (1)	2 506	2 110	84
Australia and New Zealand (1)	249 056	109 526	44
Asia (18)	861 358	133 571	16
Central Asia (1)	2 638	1 382	52
Eastern Asia (2)	246 645	40 149	16
South-eastern Asia (4)	39 938	14 648	37
Southern Asia (6)	510 720	71 077	14
Western Asia (5)	55 135	6 315	12
Europe (29)	1 032 647	454 714	44
Northern Europe (9)	175 882	28 445	16
Eastern Europe (6)	324 144	135 570	42
Southern Europe (8)	218 917	97 067	44
Western Europe (6)	305 656	193 632	63
National total (76)	3 510 679	1 453 568	41
Regional genebanks (3)*	46 776	40 781	87
International genebanks (12) **	838 222	820 273	98
Grand total	**4 395 677**	**2 314 622**	**53**

Notes: MLS = Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture. The materials under the MLS as reported by Burkina Faso (16 479), Burundi (188), the Lao People's Democratic Republic (440) and Luxemburg (12) are not included, as these countries did not report to FAO on their national *ex situ* holdings under SDG Indicator 2.5.1.a. *CATIE, CePaCT, NORDGEN. **AfricaRice, Bioversity-ITC, CIAT, CIMMYT, CIP, ICARDA, ICBA, ICRAF, ICRISAT, IITA, ILRI, IRRI.

tomato, tobacco, *Capsicum*, *Acacia*, pear, sesame, cocoa, okra, teff, flax, tea, beets, and cucumber and melon, each with over 5 000 accessions distributed. The non-Annex 1 crops among the other 62 percent of samples distributed were dragon fruit, pistachio, soybean, cocoa, avocado, coffee, mango, rubber, tomato, *Acacia*, grape, *Annona*, coconut, *Capsicum*, sugar cane, fig, pear, cotton, cucumber and melon, lettuce, guava, tobacco, okra, flax, sapote and papaya, each with more than 10 000 samples distributed. This high level of demand for germplasm of non-Annex 1 crops underscores the importance of giving attention to ways and means of further facilitating access to the genetic resources of these crops while also ensuring the fair and equitable sharing of any benefits arising from such access.

Approximately 89 percent of all the samples reported in the International Treaty dataset were distributed by CGIAR. In line with expectations, approximately 95 percent of the samples were of crops listed in Annex 1, with food-crop germplasm comprising 97 percent of all the samples reported distributed, and cereals, food legumes, vegetables, roots and tubers, forages and oil plants among those most distributed. Crops with the highest total numbers of samples distributed included wheat, maize, rice, barley, chickpea, lentil, bean, sorghum, pearl millet, Brassicaceae crops, broad bean and vetch, pigeonpea, cowpea, potato, groundnut, oat, lettuce, grasspea and other *Lathyrus*, soybean and pea, all with more than 10 000 samples distributed.

3.11.2 Situation in the regions

Sub-Saharan Africa

Kenya reports that germplasm users have shown increased interest in dryland cereals and legumes but notes that its national genebank lacks the capacity to undertake the seed-health testing necessary for the distribution of pathogen-free germplasm. Nigeria reports a significant increase in requests for materials and in distribution to users. Uganda reports multiplication activities for cereal, root and tuber, and fruit-tree accessions/varieties, as well as for vegetatively propagated crops such as coffee, ornamentals and medicinal species, for subsequent distribution to farmers.

Latin America and the Caribbean

Chile reports a significant increase in demand from public and private entities and individuals for seeds of traditional varieties. It notes, however, that a lack phytosanitary support for determining the health status of regenerated material prior to distribution has meant that it has not been possible to address these demands. Guatemala reports that the genebank of its Institute of Agricultural Science and Technology mainly distributes seeds from conserved native vegetables to local groups, as well as aromatic, condiment and medicinal plants to local communities. Peru reports that many accessions in its genebanks are not managed/conserved optimally, noting that seed numbers per accession are, therefore, frequently low and that these accessions are consequently not available for distribution. Trinidad and Tobago reports the distribution of conserved germplasm to several research institutions and growers during the reporting period.

Asia

Armenia reports that the accessibility of germplasm in its national genebank needs to be improved by establishing a web-based national catalogue and increasing public knowledge. Malaysia reports an 80 percent increase in seed requests in 2019, largely because of improved availability of information on individual accessions. Nepal reports that there were only a very few seed germplasm requests during the reporting period.

Europe

Norway reports the need to better facilitate access to the vegetative planting material in clonal archives, including access to associated documentation, and the need to identify responsible entities and procedures. The national genebank of Serbia reports the distribution of maize and pumpkin accessions to farmers in 2019.

3.11.3 Situation in regional and international genebanks

NordGen distributed 30 303 samples (9 165 accessions) of 162 genera and 358 species. More than 900 samples were distributed for *Hordeum* (4 740 samples), *Brassica* (2 144 samples and four species), *Pisum* (1 772 samples and two species), *Triticum* (1 484 samples), *Solanum* (1 229 samples of tomato), *Daucus* (1 103 samples) and *Avena* (907 samples).

WorldVeg reports distribution data for 53 different vegetable crops during the first reporting period. A total of 39 902 samples and

21 384 accessions were distributed to 87 countries as well as for internal use at the organization's headquarters.

Data provided by the International Treaty show that 3 534 349 samples (89 percent of the reported total) were distributed by CGIAR centres during the eight-year period, which equates to approximately 440 000 samples per year on average. A total of 680 067 samples (19 percent) distributed by CGIAR centres went to recipients in the country where the respective centre is located, while 2 854 282 samples (81 percent) were sent to recipients outside the country. This equates to an annual average of 85 008 samples distributed by international centres within the countries where they are located and 546 785 to recipients in other countries across the entire period. The number of annual distributions from CGIAR centres to recipients within the country where the centre is located grew on average over the eight-year period, while the number of international distributions declined slightly.

3.11.4 Summary assessment

National genebanks in 87 countries distributed more than 1.2 million accessions over the eight-year reporting period, the majority of which were to recipients within the national borders of the respective country. Several countries report increasing demands for germplasm during this time, especially for local crops. Many national genebanks, however, also report decreased capacity to carry out regeneration, viability testing and testing for pathogens – all of which are needed to ensure the distribution of sufficient, pathogen-free and viable germplasm. The lack of a searchable web-based documentation system is also reported. This limitation hinders the ability of researchers to know what is available and therefore to request materials. The international genebanks of the CGIAR and WorldVeg distributed more than 3.5 million samples of germplasm over the reporting period. More than 80 percent of distributions by the CGIAR centres were across international borders. This is in line with expectations given the widespread importance of the mandate crops of the CGIAR, the size and comprehensiveness of their *ex situ* collections and the relative ease with which they can be accessed.

3.12 Botanic gardens

There are more than 3 000 botanic gardens in the world (BGCI, 2022a) – 500 more than reported in 2009. They collectively conserve more than 640 000 taxa, variously maintained in living collections, in seed banks, in *in vitro* culture or under cryopreservation. At least 470 botanic gardens around the world have associated herbaria, many of which are large, and which together hold more than 250 million specimens. Most large herbaria are being digitalized. Many botanic gardens also maintain other collections, including ethnobotanical and carpological ones. The expansion of seed banks in botanic gardens has led to an increase in research on the seed physiology of wild species, an essential component of determining seed storage protocols. The Seed Information Database of the Royal Botanic Gardens, Kew, United Kingdom holds almost 25 000 records on seed storage behaviour (SER *et al*., 2023).

3.12.1 Seed banks associated with botanic gardens

Botanic gardens with large and sophisticated seed banks include the MSB of the Royal Botanic Gardens, Kew, and the Germplasm Bank of Wild Species in Kunming, China. At least 350 botanic gardens in 74 countries have associated seed banks, and the number is increasing (BGCI, 2022a). Table 3.32 lists the countries with the largest numbers of botanic gardens and the number botanic gardens with associated seed banks. Approximately 57 000 taxa, representing nearly 7 000 genera, are stored in botanic garden seed banks in 83 countries (BGCI, 2022b).

Botanic gardens exchange seed for a range of purposes, including for research, conservation and display. The exchange of seed material by botanic gardens is governed by the principles of the CBD and particularly the access and benefit-sharing (ABS) regulations of the Nagoya Protocol. The International Plant Exchange Network has been developed to provide a common framework for seed exchange for non-commercial use between participating botanic gardens, using an SMTA (BGCI, 2022c).

3.12.2 Conservation of plant genetic resources for food and agriculture in botanic gardens

Botanic gardens have historically focused on conserving plants of importance to humans. Their role in conserving PGRFA is increasingly being recognized. A number of countries reported on the role of botanic gardens, particularly in relation to CWR, fruit and nut crops and medicinal plants. In Uganda, for example, two botanic gardens are involved in the conservation of indigenous and native fruit trees. The field genebank of the botanic gardens of the National Academy of Sciences of Tajikistan maintains 3 251 accessions of wild fruit- tree and berry species, 500 nut-bearing species and 650 Allium species as well as a pool of 4 278 hybrids of apple and plum.

Table 3.33 provides an overview of botanic gardens holding collections of CWR of selected crops listed in Annex 1 of the International Treaty. Such collections include the breadfruit collection at the Breadfruit Institute of the National Tropical Botanic Garden in Hawaii and the mango collection at the Fairchild Tropical Botanic Garden in the United States, which maintains more than 600 mango cultivars.

A study of the role of botanic gardens in the conservation of CWR by Meyer and Barton (2019) focused on a list of 1 103 CWR taxa identified as globally valuable for food security, income generation and sustainability by Castañeda-Álvarez *et al.* (2016), many of which were found to require further conservation action. The study found that 29 percent of global priority CWR taxa were represented in botanic gardens and that botanic gardens maintained 22 global priority CWR taxa not reported by crop genebanks.

TABLE 3.32
Countries with the largest number of botanic gardens and the number of botanic gardens with associated seedbanks by country

Country	Number of botanic gardens	Number of botanic gardens with associated seed banks
United States	1 036	84
United Kingdom	211	18
China	173	13
Australia	149	24
India	138	15
Canada	122	9
Italy	115	20
Russian Federation	114	16
Germany	109	18
France	102	32
Mexico	65	10
Japan	65	2
Argentina	57	8
Republic of Korea	57	3
Brazil	49	9

Source: BCGI (Botanic Gardens Conservation International). 2022. *Advanced Garden Search*. [Cited 4 June 2022]. https://tools.bgci.org/garden_advanced_search.php

In addition to conserving CWR, botanic gardens also play an important role in the conservation of socioeconomically important species. A study by Hudson *et al.* (2021) looked at the number of socioeconomically important plant taxa conserved in the living and seed collections held in botanic gardens, as recorded in Botanic Gardens Conservation International's (BGCI's) PlantSearch database. Data were compared with a list of socioeconomically important plant taxa published by Khoury et al. (2019). At least 6 017 of the 6 941 socioeconomically important taxa (87 percent) were found to be present in botanic garden collections, with 1 456 taxa (21 percent) being held in more than 40 collections.

TABLE 3.33
Botanic garden collections of selected crops listed in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture

Crop	Genus	No. of species recorded in botanic garden collections*	No. of gardens reporting species	Important collections
Breadfruit	*Artocarpus*	79	151	National Tropical Botanical Garden, Hawaii, United States
Asparagus	*Asparagus*	159	321	Millennium Seedbank (MSB), United Kingdom
Yams	*Dioscorea*	176	106	No specific major collections
Sunflower	*Helianthus*	78	26	Denver Botanic Gardens, United States;
Sweet potato	*Ipomoea*	203	260	Singapore Botanical Garden; MSB
Apple	*Malus*	112	399	Many significant collections, including: Arnold Arboretum of Harvard University, United States; Belmonte Arboretum, Kingdom of the Netherlands; Bergius Botanic Garden, Sweden
Mango	*Mangifera*	31	160	Fairchild Tropical Botanic Garden, United States; Preston B. Bird/Mary Heinlein Redland Fruit and Spice Park, United States
Grass pea	*Lathyrus*	129	251	Chelsea Physic Garden, United Kingdom; MSB; National Botanic Gardens, Glasnevin, Ireland

Note: *Synonyms not removed.
Source: BCGI (Botanic Gardens Conservation International). 2022. PlantSearch. In: *BCGI*. [Cited 4 June 2022]. https://tools.bgci.org/plant_search.php

3.12.3 Documentation

A range of documentation systems are used across the botanic gardens community, ranging from sophisticated systems, though a range of commercial data-management systems, to simple spreadsheets. These generally focus on tracking every accession maintained by the garden and compiling associated data gathered during the garden's collecting, processing and/or growing activities. Typically, the data shared by botanic gardens relate to taxonomy, distribution, conservation status, uses and availability in gardens, and include brief descriptions of the plants. Incompatibility among the different data-management systems across botanic gardens and seed banks means that data sharing can be challenging.

3.12.4 Capacity building and networking

Botanic gardens around the world are well connected through BGCI (BGCI, 2022d) and through national and regional networks. Botanic gardens involved in seed banking are further linked through BGCI's Global Seed Conservation Challenge (BCGI, 2022e), an initiative that aims to build capacity in botanic-garden seed banking. The Seed Conservation Specialist Group[57] and the Directory of Seed Conservation Experts developed within the framework of the IUCN Species Survival Commission also facilitate networking.

The taxonomic and horticultural expertise of botanic gardens is a useful resource for PGRFA conservation. For example, staff at the Meise Botanic Garden in Belgium have been studying

[57] Further information at https://seedconservationsg.org

the genetic diversity of the wild Coffea of Central and West Africa for almost 25 years and are now working in collaboration with partners in the Democratic Republic of the Congo to build capacity to conserve Coffea genetic resources locally (Piet *et al*., 2019).

3.12.5 Awareness raising

Botanic gardens, with their comprehensive educational programmes and large numbers of visitors, have the potential to play an important role in outreach and to engage the public with issues related to crop diversity conservation and the origin of food crops. The plants in their collections can play a valuable role in connecting people to food and in raising awareness of the need to conserve potentially valuable traits. An example of this is the Food Forever campaign organized by the Crop Trust in collaboration with BGCI, the Royal Botanic Garden Edinburgh, the Royal Botanic Gardens, Kew, and the Leichtag Foundation, which calls upon the global community to protect the vast, colourful spectrum of diversity within our food system. Together, the partners have developed a toolkit and a series of Food Forever panels that are available free of charge for use by botanic gardens and other key sites to produce their own Food Forever exhibitions.[58]

3.12.6 Collaboration with plant genetic resources for food and agriculture genebanks

While the collections of botanic gardens and PGRFA genebanks are often complementary, collaboration between the two communities continues to be weak. In many countries, resources are duplicated and opportunities for sharing skills and expertise are missed. With a few exceptions, the botanic garden community does not share its collection-level data with Genesys and the crop and forest sectors. This is in part because the botanic garden sector has no equivalent data portal that enables the sharing of accession-level information. Instead, botanic gardens maintain their own accessions databases (in a variety of formats) and currently only share the names of those accessions via BGCI's PlantSearch database.[59]

The lack of collaboration may also be caused by differing institutional and reporting structures. However, the fact that a significant number of countries mention the work of botanic gardens in their country reports indicates that, in some countries at least, these barriers are being overcome. Another example is the involvement of botanic gardens in the recent development of an integrated genetic resources strategy for Europe through the GenRes Bridge project.[60]

Several countries, including Azerbaijan, Ethiopia and Lebanon, report establishing one or more new botanic gardens. In several countries, botanic gardens are reported to be an integral part of national PGRFA conservation efforts, sometimes with specific responsibilities, for example in Egypt, El Salvador, Estonia, Indonesia, Kyrgyzstan, Mexico, Nepal, Tajikistan, Tunisia, Uganda and Zimbabwe. Some countries report the need to establish better collaboration between PGRFA genebanks and botanic gardens (e.g. Bangladesh, Brazil, Mexico and Nepal). Several countries (e.g. Armenia, Botswana, Tajikistan and Uganda) report that one or more botanic gardens focus on local or regional native flora. The conservation of CWR in botanic gardens is mentioned by Tajikistan and Zimbabwe. The maintenance of herbaria by botanic gardens is reported by Cuba, Kyrgyzstan, Romania, Türkiye and Zimbabwe. In El Salvador, the Plan de la Laguna Botanic Garden assists the national PGRFA programme in planning collecting missions. In Romania collaboration between genebanks and botanic gardens focuses on research and assistance in education.

[58] Further information at https://www.bgci.org/our-work/projects-and-case-studies/food-forever-global-exhibition

[59] Further information at https://www.bgci.org/resources/bgci-databases/plantsearch

[60] Further information at http://www.genresbridge.eu

3.12.7 Summary assessment

Botanic gardens are numerous and widespread across the world. The enormous species diversity they conserve is without question a major contribution to global efforts to conserve plant species, including many PGRFA. The increasing focus on conserving species producing orthodox seeds, including in seed banks, means that there is incentive to seek much closer collaboration between PGRFA genebanks and botanic gardens. Botanic gardens possess considerable experience in plant identification, and train people around the world in the skills needed to maintain and conserve plant diversity. They are very experienced in creating public awareness and showcasing interesting and important species. They also have a well-functioning global network.

3.13 Gaps and needs

Complementary conservation

In situ and *ex situ* conservation strategies need to be integrated and complementary to achieve sustainable, secure, efficient and cost-effective long-term conservation of PGRFA. *Ex situ* methods do not allow natural evolution to occur, but they are a crucial means of protecting genetic resources from immediate threats. In contrast, PGRFA located *in situ* adapt and evolve over time in response to changing environmental conditions and, therefore, represent a dynamic source of diversity for future collecting and use. Another point to note concerning complementarity is that different *ex situ* conservation approaches, such as field genebanks, *in vitro* conservation and cryopreservation, can also be used as complementary strategies for safeguarding germplasm.

Policy support

Several countries report a lack of policy support, for example the lack of a national strategy for the conservation of PGRFA, which often results in limited or sporadic funding for hiring qualified staff, building or maintaining infrastructure, and buying equipment and supplies. The International Treaty calls on its Contracting Parties to integrate *ex situ* conservation into their agriculture and rural development policies and programmes. *Ex situ* conservation should represent a core component of national PGRFA strategies and as such should have adequate provision in national programmes.

The MLS of the International Treaty also serves as a catalyst for research and development of PGRFA. However, it focuses at present on a limited number of crops (Annex I crops). In the long run, this may have repercussions for the sustainability of crop production systems by leading to the neglect of other species that are important for food security and nutrition. The expansion of Annex I to address this issue is under discussion by the International Treaty.

The CBD is of particular relevance in the context of collecting materials from farmers' fields/stores or community areas, including natural habitats, as prior informed consent and mutually agreed terms may be required (CBD, 2018). National and international phytosanitary regulations and quarantine laws define conditions for the safe acquisition and exchange of germplasm. Safety-specific phytosanitary standards for the international exchange of germplasm have not yet been developed, and requirements for germplasm shipment often vary from country to country, necessitating collaboration with national and regional plant-quarantine organizations.

Quality of collections

Ex situ conservation in genebanks is underpinned by common principles (FAO, 2014). These can be translated into a series of interrelated operations (FAO, 2022a,b,c). Many national genebanks need to develop and implement standard operating procedures and quality management systems (CGIAR Genebank Platform, 2021b) that define in detail how these operations should be carried out.

Documentation of collections

Only limited progress in documentation of *ex situ* collections has been reported. Many countries still struggle with documenting passport data and other genebank management information. While some international and regional centres are adopting new genebank management information systems, broader adoption is still required among national genebanks. Ongoing initiatives in this field need to be scaled up to reach more national genebanks. There is a need for an overall improvement in data consistency and accessibility of national *ex situ* collections, including through greater integration of national systems with international portals such as WIEWS, Genesys and EURISCO, and the use of tools such as DOIs and the Embedded Genesys, the latter of which can facilitate the publication of genebank inventories in national websites.

Safety duplication and regeneration backlogs

Despite progress in increasing the safety duplication of *ex situ* collections in recent years, thanks particularly to the opportunities offered by SGSV for seed germplasm, many genebank collections are still not (or remain only partially) safety duplicated. This is particularly the case for collections of species that produce recalcitrant seeds or propagate vegetatively for which there are no backup storage facilities equivalent to SGSV. Attention should also be given to species collections that are concentrated in one or only a few genebanks globally and are not safety duplicated. Many genebanks have difficulties regenerating or multiplying their collections adequately, and backlogs remain unsustainably high.

Financial support for ex situ conservation

Ex situ conservation is intended to be for the long term, ideally in perpetuity, and so it requires sustainable and adequate funding for infrastructure and equipment, sufficient numbers of well-trained staff and timely purchasing of perishable supplies. Inadequate or unsustainable funding, which affects many genebanks, may hamper conservation efforts and even result in the loss of germplasm. Furthermore, many routine conservation activities are funded predominantly through short-term projects. While these initiatives are commendable, more attention needs to be given to long-term financial stability to allow proper planning and adequate staffing of genebanks and other *ex situ* conservation activities.

The lack of a sustainable funding mechanism for conservation activities is by far the most commonly reported finance-related gap. These concerns relate particularly to viability testing, seed and plant health monitoring, regeneration and multiplication, characterization and safety duplication. Countries also indicate that financial limitations have contributed to difficulties with (i) hiring sufficient staff, (ii) maintaining and/or expanding facilities such as cold storage, seed drying rooms and seed health laboratories, (iii) conserving germplasm in field genebanks, (iv) obtaining specialized facilities for molecular characterization, *in vitro* conservation or cryopreservation, and (v) purchasing state of the art equipment and the necessary associated consumables.

Human capacity

Shortages of adequately trained staff cause severe constraints to the efficient and effective *ex situ* conservation of PGRFA. Gaps include a lack of expertise in critical subjects such as botany, plant taxonomy, plant ecology, conservation and population genetics, physiology, pathology, statistics and informatics. Additionally, curricula in genetic resources science are declining globally. The appeal of molecular science has further affected the availability of the above-mentioned categories of expertise.

Networking and collaboration

As many countries do not have sufficient human capacity, funds or facilities to adequately carry out germplasm management operations, many valuable collections are in jeopardy. There is a need for greater cooperation among genebanks and institutions involved in the conservation and sustainable use of PGRFA at the national, regional and international levels to strengthen human and technical capacity and share facilities and know-how. Such cooperation could also include the exploration of valuable traits for potential use in breeding programmes. Collaboration with the private plant-breeding sector may also be worth expanding.

There is also a need for adequate coordination of long-term conservation programmes at the national level and better networking among the stakeholders involved. Strong national PGRFA programmes require the involvement and participation of all relevant stakeholders. Cooperative activities involving botanic gardens and national, regional and international genebanks need to be strengthened through specific organizational arrangements.

Better coordination within and between institutions at the country level is a necessity. For example, collecting CWR and WFP often requires coordination between the genebank, which is frequently under the country's agriculture ministry, and the environment ministry, which often oversees the areas where wild PGRFA are found. Other examples include the need for coordination between genebanks, research stations and academic institutions within countries, especially for activities such as safety duplication but also for the outsourcing of regeneration and multiplication, viability testing, health screening and molecular characterization.

Improved collaboration between national, regional and international genebanks and institutes is also needed. The success of existing regional genebanks could provide a model for the provision of support to national programmes via training, backup storage and collaboration in activities such as viability and germplasm-health testing, regeneration and characterization, including molecular characterization. For example, regional genebanks provide countries with invaluable resources, especially in terms of maintaining their base collections. Collaboration with universities, other research institutes and the private sector should also be established or strengthened, both in terms of outsourcing activities and in terms of the funding of mutually beneficial activities that enhance germplasm use.

The funding and coordination of regional efforts to conserve base collections needs to be improved, thus freeing up human resources at the national level to conduct research on conservation and sustainable use. The regional centres should provide opportunities for training and secondment of national staff to undertake tasks at the centres on a rotational basis.

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Chapter 4

THE STATE OF SUSTAINABLE USE

Chapter 4

The state of sustainable use

4.1 Introduction

Article 6 of the International Treaty commits its Contracting Parties to "develop and maintain appropriate policy and legal measures that promote the sustainable use of plant genetic resources for food and agriculture" (FAO, 2009). Though the International Treaty does not explicitly define the concept of the sustainable use of PGRFA, it does identify a set of measures whose implementation falls within the remit of Article 6. These measures, which encompass the direct utilization of PGRFA by farmers and other end-users and their indirect exploitation in research and development, include broadening the genetic base of crops through pre-breeding and domestication, plant breeding, utilization of locally adapted crops, varieties and underutilized species, release of crop varieties and seed distribution, and development and maintenance of diverse farming systems.

Further underscoring the importance of this article of the International Treaty, the Commission in 2013 adopted the following target for the sustainable use of PGRFA: "By 2020, there has been an increased use of plant genetic resources for food and agriculture to improve sustainable crop production intensification and livelihoods while reducing genetic vulnerability of crops and cropping systems" (FAO, 2013). This target is instructive in that it recognizes both that the use of PGRFA should increase the contribution of cropping systems to food security and nutrition and that it should increase the genetic diversity within such systems.

The GPA2, the globally agreed framework for the conservation and sustainable use of PGRFA, is an implementing mechanism for the International Treaty. Five of the 18 priority activities of the GPA2 stipulate actions to be taken to achieve the sustainable use of PGRFA. These priority activities, which are aligned with the measures stipulated in Article 6 of the International Treaty, address the following themes: characterization, evaluation and development of subsets of germplasm collections; plant breeding, genetic enhancement and base-broadening; diversification of crop production systems; development and commercialization of all varieties, especially FV/LR and underutilized species; and seed production and distribution.

Countries and other relevant stakeholders were invited to report on progress made during the period 2014 to 2019 in the implementation of the priority activities of the GPA2 using a specifically designed reporting format (FAO, 2019; see Chapter 1) that provided a uniform set of indicators and questions. In addition to responses based on this template of indicators and questions, respondents also provided summative narratives as supplementary information. For the five priority activities pertaining to the sustainable use of PGRFA, there were 19 indicators and 16 associated questions. While most of the data used in preparing the SoW3 were provided by countries, information from the literature, databases and other validated sources was used where relevant to provide context.

This chapter describes progress towards the sustainable use of PGRFA, as envisaged in the International Treaty and the GPA2, since 2014. Its structure corresponds to the relevant five priority activities of the GPA2.

4.2 Overview of sustainable use

During the reporting period, progress was made in the sustainable use of PGRFA, in particular through germplasm characterization, plant breeding, broadening the genetic base of crops through pre-breeding, the utilization of locally adapted varieties and underutilized species, the release of crop varieties and seed delivery systems, and the promotion of diverse farming systems.

Country data indicate a significant increase between 2012 and 2019 in the number of accessions characterized, as well as progress in the development of thematic collections for traits of interest. This facilitated better understanding and improved use of germplasm collections. By the end of 2019, almost 800 000 germplasm accessions – held by 289 genebanks in 70 countries, and representing 30 percent of the total genebank holdings in these countries – were characterized, on average, for 24 traits. Recent advances in biotechnologies, especially next-generation sequencing and high-throughput phenotyping, are increasingly being used to improve the efficiency of germplasm characterization and evaluation. An overall increase in the adoption of DNA marker technologies for the assessment of genetic variation was reported by 53 countries from five regions. However, not all countries have access to these technologies and many lack the capacity to utilize them. Ensuring that all countries can fully benefit from the diversity of PGRFA will require improvements to collaboration, capacity-building and technology transfer.

Because of suboptimal information and data management systems, most existing characterization and evaluation data are not publicly available. The ongoing lack of such data often hinders the targeted selection of accessions that have specific traits. Substantial action to address this constraint is needed.

Over 350 national research organizations from 76 countries reported the use of pre-breeding (the introgression of novel traits from non-adapted materials into breeding populations) for a total of 322 crop species. While pre-breeding activities took place in all regions during the reporting period, they do not appear to have yet become a routine crop improvement strategy. This suggests that there is a largely unused opportunity for strategic collaboration between genebank managers and breeders.

Breeding activities were reported by 87 countries, targeting almost 500 crop species across all major crop groups. While yield continues to be the prioritized trait in crop breeding programmes, resistance to biotic and abiotic stresses – especially as a climate change adaptation strategy – and quality traits related to improved nutrition are also frequently cited as breeding objectives. The number of countries reporting farmer participatory plant breeding more than doubled relative to the number that reported this activity for the SoW2.

Alongside important advances in high-throughput and low-cost genotyping, in particular genome sequencing, significant advances in the morphological and biochemical characterization of plants are creating new opportunities. Country data indicate that the reporting period saw an upsurge in the application of modern plant breeding techniques, in particular genomic selection and the more recent genome editing technologies, including CRISPR/Cas9. However, modern biotechnologies and molecular genetic tools remain too costly for regular use in crop breeding in many national programmes, which are often insufficiently funded even to support capacities for traditional breeding.

Activities aimed at increasing intraspecific and/or interspecific diversity in crop production systems were reported by 73 countries. In addition to mixed cropping and crop rotation, diversification initiatives are increasingly focusing on the introduction of new crops, reintroduction of previously used crops and domestication of wild species.

Countries report various measures aimed at enhancing the cultivation of FV/LR and promoting their development and commercialization. Over 500 FV/LR were registered in 29 countries across all regions during the reporting period. Most registrations occurred during the last two years of the reporting period (2018 and 2019), reflecting the resurgent interest in FV/LR and growing opportunities to market them. This development contrasts with the progressive discontinuation of the cultivation of many FV/LR, perhaps reflecting the declining number of farmers – and with this a loss of knowledge associated with FV/LR – as well as the abandonment of marginal cropping areas.

Nearly 1 400 programmes targeting FV/LR and underutilized crops or species were reported from 75 countries, including programmes addressing research, crop improvement, crop processing, public awareness, seed distribution, market development and policy changes. Among these programmes, 412 were reportedly specific to FV/LR and 159 were specific to underutilized crops or species. Despite advances in the development and commercialization of FV/LR and underutilized species, many countries still lack national policies and legal frameworks to support such initiatives. Research on PGRFA and efforts to improve their utilization need to be stepped up.

Informal and formal seed systems co-exist in all countries. Forty countries, more than two-thirds of them developing countries, report that there were improvements in their seed systems between 2012 and 2019, developments that facilitated farmers' adoption of the most suitable crop varieties. The global seed market increased in value from USD 36 billion in 2007 to over USD 50 billion in 2020. The cost of quality seeds of suitable crop varieties remains an important constraint to their wider use in many developing countries. This could be mitigated through targeted policies and incentives that address components of the seed value chain.

4.3 Germplasm characterization, evaluation and development of trait-specific sets

The utility of large germplasm collections is typically constrained by a lack of knowledge about the traits that would be useful for the genetic improvement of crops. Mining specific alleles for breeding from large germplasm collections is both resource- and labour-intensive. Generating reliable data from germplasm characterization and evaluation, and facilitated access to these data, could support the creation of trait-specific collection subsets. Such subsets would facilitate the identification of particular germplasm accessions that harbour heritable traits of interest. To achieve this, however, there is a need to increase the quantity and improve the quality of the characterization and evaluation information generated, and to implement mechanisms for documenting and providing access to this information.

The characterization and evaluation of plant germplasm using standard descriptors – such as those published by Bioversity International and UPOV – are critically important for the efficient conservation and use of genebank collections. These descriptors refer to morphological traits with high heritabilities.

In recent years, there has been a significant increase in the number of accessions characterized, and progress has been made in developing thematic subsets for characters of interest based on data generated from the characterization and evaluation of genebank holdings. This has facilitated better understanding of the diversity of germplasm accessions and hence increased the potential to use them in plant breeding and/or research activities. Workable subsets of germplasm that capture sufficient genetic variation (core collections representing 10 percent of all accessions and mini core collections representing 1 percent) have been created for rice, maize, soybean, common bean, chickpea, groundnut, pigeonpea, sorghum and millets (Guo *et al*., 2014; Kuzay *et al*., 2020).

4.3.1 Germplasm characterization

A summary of the status of characterization of *ex situ* collections is presented, by region and subregion, in Table 4.1. As of the end of 2019, 771 066 germplasm accessions held by 289 genebanks in 70 countries and representing

TABLE 4.1
Level of morphological characterization of *ex situ* collections, by region and subregion

Region	Subregion	Number of countries	Number of accessions conserved *ex situ*	Number of accessions characterized	Percentage of accessions characterized	Average number of traits per accession characterized	Average number of traits per accession conserved *ex situ*
Northern Africa	Northern Africa	4	124 195	37 759	30	22	7
		4	**124 195**	**37 759**	**30**	**22**	**7**
Sub-Saharan Africa	Eastern Africa	8	159 698	78 826	49	21	10
	Southern Africa	2	8 995	1 313	15	25	4
	Western Africa	6	24 741	5 047	20	16	3
		16	**193 434**	**85 186**	**44**	**21**	**9**
Latin America and the Caribbean	Central America	6	84 777	8 922	11	24	3
	Caribbean	2	20 050	14 315	71	36	25
	South America	8	335 095	60 962	18	30	5
		16	**439 922**	**84 199**	**19**	**30**	**6**
Oceania	Melanesia	1	1 630	225	14	49	7
	Australia and New Zealand	1	265 655	2 074	1	10	0
		2	**267 285**	**2 299**	**1**	**14**	**0**
Asia	Central Asia	2	70 787	10 429	15	7	1
	Eastern Asia	2	243 900	94 441	39	20	8
	South-eastern Asia	1	13 059	8 533	65	32	21
	Southern Asia	5	518 908	140 193	27	19	5
	Western Asia	5	66 351	3 592	5	16	1
		15	**913 005**	**257 188**	**28**	**19**	**5**
Europe	Northern Europe	3	6 069	806	13	18	2
	Eastern Europe	6	288 578	87 718	30	12	4
	Southern Europe	4	77 160	7 010	9	49	4
	Western Europe	4	284 848	208 901	73	34	25
		17	**656 655**	**304 435**	**46**	**28**	**13**
Total		**70**	**2 594 496**	**771 066**	**30**	**24**	**7**

Note: Figures are based on data from 289 genebanks in 70 countries.

30 percent of the total genebank holdings in these countries,[1] were characterized, on average for 24 traits. The proportion of characterized germplasm relative to the total holdings was higher than 50 percent in 22 countries, between 20 percent and 50 percent in 12 countries, between 10 percent and 20 percent in 15 countries, and less than 10 percent in the remaining 21 countries, eight of which were in sub-Saharan Africa. The regional averages for Western Europe, the Caribbean and South-eastern Asia were higher than 50 percent, and they ranged between 20 percent and 50 percent in Northern, Eastern and Western Africa, Eastern and Southern Asia, and Eastern Europe.

[1] Total genebank holdings as per the 2019 SDG Indicator 2.5.1.a report.

The number of accessions in *ex situ* holdings, the proportion characterized and the average number of traits per characterized accession, as reported by 289 genebanks from 70 countries, are presented by main crop groups and genera in Table 4.2.

TABLE 4.2
Status of germplasm characterization, by crop group for selected genera

Crop group	Genus	Accessions (No.)	Characterization (%)	Average number of traits	Crop group	Genus	Accessions (No.)	Characterization (%)	Average number of traits
Cereals	*Triticum*	393 410	36	21	Oil plants	*Glycine*	54 823	26	20
	Oryza	223 674	28	28		*Sesamum*	24 435	20	20
	Hordeum	198 115	47	25		*Helianthus*	14 963	24	7
	Zea	113 899	22	21		*Carthamus*	11 711	10	22
	Sorghum	81 916	29	30		*Brassica*	8 251	44	20
	Avena	36 601	28	18		*Guizotia*	3 877	34	20
	Eleusine	20 658	22	16	Pulses	*Phaseolus*	94 863	25	27
	Triticosecale	14 915	33	16		*Vigna*	47 199	49	17
	Aegilops	13 484	21	10		*Lathyrus*	46 706	35	31
	Eragrostis	5 540	88	15		*Cicer*	46 566	25	16
Pseudo-cereals	*Amaranthus*	15 153	17	23		*Arachis*	28 320	14	22
	Chenopodium	8 054	85	35		*Vicia*	17 668	34	23
	Fagopyrum	3 622	30	18		*Lens*	17 558	28	20
Forages	*Medicago*	44 063	9	17		*Lupinus*	15 510	34	47
	Trifolium	32 888	11	20		*Lablab*	3 694	22	26
	Festuca	14 265	46	29	Roots and tubers	*Solanum*	30 450	59	33
	Dactylis	13 416	64	20		*Ipomoea*	9 171	29	36
	Lolium	12 818	57	39		*Manihot*	7 336	35	43
	Vicia	12 198	21	24		*Dioscorea*	2 807	22	40
	Poa	5 345	72	25		*Oxalis*	1 739	100	21
	Phleum	4 953	76	25		*Colocasia*	1 380	12	50
Fruit plants	*Vitis*	62 832	9	42	Sugar plants	*Saccharum*	9 206	55	27
	Malus	24 534	24	32		*Beta*	4 342	37	35
	Prunus	17 354	18	22	Vegetables	*Solanum*	46 736	30	27
	Pyrus	10 881	12	30		*Capsicum*	29 551	25	35
	Citrus	4 585	37	21		*Cucumis*	23 650	31	31
	Musa	2 734	37	89		*Brassica*	23 229	45	22
	Fragaria	2 509	42	20		*Cucurbita*	20 169	14	34
	Annona	1 519	54	38		*Allium*	13 513	41	15
	Persea	1 491	35	31		*Lactuca*	8 817	44	24
Herbs and spices	*Brassica*	12 206	9	27		*Raphanus*	4 164	46	26
	Trigonella	2 963	24	13		*Daucus*	3 650	29	27

Note: Based on data from 289 genebanks in 70 countries.

Cereals accounted for 50 percent of all the characterized germplasm accessions. About 34 percent of cereal germplasm accessions in the 70 reporting countries were characterized, on average for 23 traits. The most represented genus was *Triticum*, with 141 723 accessions morphologically characterized (36 percent of the total held by the reporting countries), on average for 21 traits. The proportion of germplasm accessions characterized was 28 percent for rice, 47 percent for barley and 22 percent for maize. Of the 222 305 vegetable germplasm accessions from 248 genera in the genebanks of the reporting countries, 30 percent, belonging to 131 genera, were characterized using about 26 traits on average. Tomatoes and eggplants accounted for 9 927 and 2 223 accessions characterized, respectively, while the remaining 1 920 accessions belonged to 48 species of CWR of these two crops. About 96 000, or 29 percent, of the pulse accessions conserved were characterized, using on average 24 morphological traits. Similarly, 40 percent of the combined germplasm accessions of cowpea, green peas, lupins and lablab bean were characterized for an average of 26 traits.

The proportion of conserved germplasm accessions reported characterized was above 70 percent of the total in Cuba, Egypt, Ethiopia, Germany, the Kingdom of the Netherlands, Madagascar, Mali, Peru and Togo. Brazil reported the characterization of a total of 100 645 accessions belonging to 129 taxa. On average, 19 traits were used for the characterization of these accessions. For instance, the Embrapa soybean collection, totalling 55 000 accessions, was fully characterized on the basis of 15 characters. In Canada, several crop species, including pea, flax, wheat, oat, buckwheat, triticale, sunflower and several Brassicaceae, were characterized and evaluated. This included collaborative efforts between plant pathologists and plant breeders to screen crop germplasm for resistance to fungal diseases. For example, 14 000 accessions of wheat were screened for stem rust, leaf rust, leaf spot and *Fusarium* head blight, 28 000 accessions of oat for crown rust and wilt, and 3 500 accessions of flax for pasmo. The screening of lentil, chickpea and canola germplasm resulted in the identification of accessions with improved resistance to important fungal pathogens, such as *Ascochyta* blight and clubroot.

The extent of improvement in the level of characterization of *ex situ* collections since the time of SoW2 (FAO, 2010), however, is not easily quantifiable, and the latest data show the overall level of characterization to be lower than that in 2008. The discrepancy may in part be a result of the different number of reporting countries, i.e. 42 in 2008 and 70 in 2019, and the different type of data reported, percentage estimates in 2008 versus accession-level information in 2014 and 2019. The relatively low number of countries reporting on characterization as compared to those reporting on their genebank holdings appears to indicate limitations in terms of linking characterization data to conserved germplasm.

Progress in terms of the level of characterization of germplasm collections could be assessed for 102 genebanks in 33 countries that reported twice over the 2014 to 2019 period. In nine of these genebanks, none of the accessions conserved were characterized in 2014. In the others, 368 922 accessions, about 36 percent of the holdings, were characterized for an average of 22 morpho-agronomical traits. Five years later, three genebanks still held collections with no characterization data. In the remaining 99 genebanks, 548 825 accessions, about 52 percent of the holdings (1 048 544 accessions), were characterized for an average of 25 traits.

A comparison between the status of germplasm characterization in the 102 genebanks showed a 48 percent increase in the number of accessions characterized, from 368 922 to 548 825 out of more than 1 048 000 *ex situ* accessions conserved. The average number of traits used for the characterization of an accession also increased, from 22 in 2014 to 25 in 2019. Among these 102 genebanks, 15 in 13 countries characterized more than 1 000 accessions each during the five-year period (Table 4.3). Notably, a number of genebanks further characterized accessions that had previously been characterized for additional traits. For example, at the at the IPK genebank in Gatersleban, Germany, the number of traits characterized increased by 67 percent. At the same genebank, historical characterization data that had been collected since 1946 were also digitized and analysed.

In Germany, the national evaluation programme (EVA and EVA II) for cereals, operating in private–public partnership mode and involving 15 breeding companies and three scientific organizations, resulted in the evaluation of 2 292 wheat and 1 865 barley accessions for resistance or tolerance to eight pathogens. The evaluation programme served as a blueprint for the successful development of the European Cooperative Programme for Plant Genetic Resources European Evaluation Network in 2018, which was implemented through a series of projects funded by Germany's Federal Ministry of Food and Agriculture.

4.3.2 Molecular characterization

Advances in molecular biology, in particular DNA sequencing and genotyping technologies, provided significant impetus to the use of plant genomics for germplasm characterization and evaluation and crop improvement during the reporting period. The second generation of DNA markers, including simple sequence repeat (SSR) markers, were still being used for molecular characterization of smaller PGRFA collections and subsets during the reporting period. However, owing to their cost-efficiency and suitability for assaying large numbers of samples, next generation sequencing (NGS)

TABLE 4.3

Changes in the level of morphological characterization of *ex situ* collections during 2014–2019 for genebanks that characterized over 1 000 new accessions during the period

Country	Genebank	Number of accessions conserved as of 31 December 2019	Percentage of accessions characterized as of		Average number of characterized traits per accession conserved	
			30 June 2014	31 December 2019	30 June 2014	31 December 2019
Czechia	CRI	45 895	57	62	9	10
Ecuador	DENAREF	21 902	11	55	3	18
Germany	IPK	129 815	100	100	21	36
	JKI-Grapevine	2 929	0	42	0	3
	JKI-Fruit	1 601	40	100	22	23
Iran (Islamic Republic of)	HSRI	70 759	40	58	4	8
Japan	NARO	224 353	9	41	1	8
Malaysia	GB, MARDI	12 213	22	70	7	22
Mali	URG	2 137	29	100	4	9
Mongolia	IPAS	19 547	4	13	1	2
Morocco	INRA CRRAS	69 628	9	14	1	1
Nepal	NAGRC	6 470	43	68	5	8
Peru	INIA-EEA.DONOSO	1 899	44	100	30	73
Poland	IHAR	76 160	0	56	0	3
Sudan	ARC	17 177	2	65	0	25
	Total/average	702 485	31	56	6	13

methods based on reduced representation, such as genotyping by sequencing (GBS), specific locus amplified fragment sequencing (SLAF-seq) and restriction-site associated DNA (RAD) sequencing, are increasingly being used for genetic profiling of genebank collections.

In recent years, whole genome sequencing and other high-density genotyping techniques, such as whole genome re-sequencing (WGRS), GBS, single nucleotide polymorphism (SNP) arrays and kompetitive allele-specific PCR (KASP), which enable in-depth genetic characterization of large crop germplasm collections, have been growing in importance, especially in the context of international collaborations. Examples included the whole genome sequencing of hundreds of diverse accessions of rice (Wang *et al.*, 2018), chickpea (Varshney *et al.*, 2019, 2021a), wheat (Sansaloni *et al.*, 2020), maize (Romay *et al.*, 2013), soybean (Bandillo *et al.*, 2015), sorghum (Girma *et al.*, 2020), pepper (Tripodi *et al.*, 2021), cassava (Bredeson *et al.*, 2016; Ramu *et al.*, 2017; Hu *et al.*, 2021), sunflower (Hübner *et al.*, 2019), common bean (Wu *et al.*, 2020), pigeonpea (Varshney *et al.*, 2017a), pearl millet (Varshney *et al.*, 2017b) and lettuce (Wei *et al.*, 2021). These activities underscored the potential of "germplasm genomics" for plant genetics and improvement in the post-NGS era.

The use of DNA marker technologies for the assessment of genetic variation was reported by 53 countries from five regions. In about half the 32 countries that reported for both 2012–2014 and 2014–2019, there was an overall increase in the adoption of DNA marker technologies for the assessment of genetic variation, particularly in the assessment of diversity, either as a stand-alone method or in combination with pedigree studies or other methods.

Northern Africa

In Egypt, different molecular techniques, such as inter simple sequence repeat (ISSR), SSR and amplified fragment length polymorphism (AFLP), as well as DNA barcoding, were used to characterize various *Vicia* species, cantaloupe, broad beans, clover, wheat, pomegranate and grapes.

Sub-Saharan Africa

A total of 30 accessions of sorghum were characterized using molecular techniques in Botswana, 33 cowpea accessions in Eritrea, 113 cowpea accessions and 80 taro accessions in Ghana, 30 rice accessions in Zambia, and 49 sorghum accessions in Mali. In Kenya, NGS was used to assay the genome of finger millet, leading to the identification of 10 327 SSR and 23 285 SNP markers, which were polymorphic across wild and cultivated accessions.

Europe

At IPK in Gatersleben, Germany, the entire barley collection of more than 20 000 accessions, and about 22 000 wheat accessions, were assayed using GBS. Genetic reference profiles for future validation of varieties were generated for 1 544 apple, 476 cherry and 192 strawberry varieties at the German fruit genebank. Underutilized native species were also characterized under the auspices of a series of innovative projects, which involved both phenotypic and genotypic characterization and evaluation. The German Federal Ministry of Education and Research (BMBF) funded research projects to genotype, phenotype and sequence the accessions conserved at the IPK federal genebank. Several projects, including public–private partnership projects funded by the German Federal Ministry of Food and Agriculture and BMBF, conducted genome sequencing of wheat and barley accessions and established pangenomes. Similar work on oats was ongoing at the end of 2019.

In the Kingdom of the Netherlands, the molecular characterization of germplasm accessions was implemented through the 150 Tomato Genome Sequencing Project, the International Lactuca Genomics Consortium, the Capsicum Genome Initiative, the Dutch Research Council-funded project "Healthier lettuces for healthier food" (lettuce metabolomics), the

LettuceKnow project (lettuce transcriptomics) and a cooperative project with the Beijing Genomics Institute in Shenzhen, China.

At the Swiss National Genebank, 502 bread wheat (*Triticum aestivum*) and 293 spelt *(Triticum aestivum* subsp. spelta) accessions were analysed using a 15K SNP array. Notably, this demonstrated the importance of old landraces as sources of novel alleles for crop improvement (Müller *et al*., 2018).

In the United Kingdom, a large-scale and cost-efficient functional genomics platform was established for Targeting Induced Local Lesions in Genomes (TILLING) for *Brassica napus*, *Brasica rapa* and rice. The characterization of 1 779 accessions, including landraces and elite lines, was carried out using Wheat Breeders' Array to develop future wheat cultivars. In addition, KASP markers were employed for quality assurance of mapping populations of wheat. At the John Innes Centre, 712 pea accessions were sequenced with 20 times the coverage.

Molecular characterization was applied to several subsets of PGRFA in Italy. At the Research Centre for Olive, Fruit and Citrus Crops , about 400 peach accessions were analysed with the IPSC 9K SNP array (Micheletti *et al.*, 2015; Verde *et al.*, 2012). Moreover, the entire peach collection of about 900 accessions was characterized with SSR markers. About 400 apple accessions local to central Italy were characterized with 20K SNP arrays. A subset of 200 bread wheat accessions was analysed using SNPs and phenotyped for relevant agronomic and qualitative traits (Lazzaro *et al.*, 2019; Ormoli *et al.*, 2015; Talini *et al.*, 2020).

Northern America

At the Plant Gene Resources of Canada genebank in Saskatoon, genetic sequence data were generated on subsets of germplasm of 20 000 accessions of oat (including wild species), barley (including wild species), wheat, flax, maize, soybean and oilseed *Brassica* species as part of a six-year project that started in 2017 and was expected to address almost 35 000 accessions.

Latin America and the Caribbean

The use of molecular markers, particularly microsatellites, to characterize and evaluate small subsets of germplasm collections was reported by Guatemala (e.g. for maize, beans, cacao and loroco), Mexico (genetic fingerprinting with microsatellites and genome studies in maize and avocado), Nicaragua (for about 40 populations of red beans and their wild relatives), Peru (e.g. for chili, quinoa, yuca, potato, custard apple, camu camu and sweet potato) and the Bolivarian Republic of Venezuela (to detect diseases tolerance in tomato and characterize germplasm collections of *Musa*, cacao, beans and vegetables).

International centres

Nine international research centres reported in 2019 that a total of 128 712 accessions had been sequenced (Table 4.4). The proportions of the total number of accessions conserved that were sequenced ranged from 0.1 percent to 46 percent.

TABLE 4.4

Number and percentage of conserved accessions sequenced in international centres, 2019

Centre	Number of accessions conserved	Number of conserved accessions sequenced	Percentage of conserved accessions sequenced
AfricaRice	21 360	8 888	41.6
Bioversity	1 617	511	31.6
CIAT	67 787	4 926	7.3
CIMMYT	180 846	83 206	46.0
CIP	16 032	17	0.1
ICARDA	140 111	24 319	17.4
ICRAF	5 219	5	0.1
ICRISAT	128 155	1 719	1.3
IRRI	132 166	5 121	3.9
TOTAL	**693 293**	**128 712**	**18.6**

Note: Figures reported by the respective centres in December 2019.

4.3.3 Development of core, mini-core and trait-specific subsets of germplasm collections

Since the publication of the SoW2, information on several subsets of germplasm collections has been made available on online platforms that store PGRFA data such as Genesys, which publishes information on 262 subsets of different crops.[2] These include core collections for sorghum (2 246 accessions), pearl millet (2 094 accessions), soybean (small seeded: 1 466 accessions; large seeded: 111 accessions), subterranean clover (97 accessions) and cassava (629 accessions). Also accessible from Genesys are mini-core collections for rice (600 accessions), *Oryza glaberrima* (350 accessions), *Triticum timopheevii* (92 accessions), *Aegilops tauschii* (40 accessions) and cowpea (376 accessions). The generation of large-scale sequencing and genotyping data in recent years has facilitated more detailed investigations of existing diversity panels, as demonstrated in rice (Kumar *et al*., 2020), wheat (Pascual *et al*., 2020) and common bean (Kuzay *et al*., 2020), which in turn has allowed the optimization of these subsets to provide better representations of the genetic diversity of the species.

During the reporting period, characterization and evaluation data were used in several countries to develop trait-specific subsets of germplasm accessions. In Sweden, trait-specific subsets of germplasm accessions were developed for the following ten crops and sets of characteristics:

- barley – growth habit and row type;
- wheat – growth habit;
- hop – morphological, chemical and sensory characteristics for brewing beer;
- asparagus – morphological and sex traits;
- potato – morphological and storage properties;
- onion – morphological and storage properties;
- garlic – morphological and sensory traits;
- horse radish – morphological and chemical (sinigrin) traits;
- rhubarb – morphological and chemical (oxalic acid) traits; and
- Jerusalem artichoke – morphological and sensory traits.

In the Kingdom of the Netherlands, 512 trait-specific collection subsets were documented in the period from 2012 to 2019. In Belarus, 68 trait-specific collection subsets were defined for various cereals, pulses, fruit plants, and oil and fibre plants. In Egypt, germplasm accessions with tolerance to abiotic stresses were identified, including accessions of alfalfa (drought and salinity tolerance), lentil (high-temperature tolerance) and wheat (drought and heat tolerance).

Eritrea, Ethiopia, Indonesia, Norway, Sweden and Türkiye report that more effort and resources need to be put into the development of trait-specific collections as well as core and mini-core collections. One of the major constraints to progress in this area of activity has been the poor level of feedback from germplasm recipients and a lack of sharing of results/publications originating from the use of the received germplasm.

During the reporting period, 12 international and regional centres published a total of 2 588 subsets, most of which were developed by CIAT during the 2012 to 2014 period (see Table 4.5).

4.3.4 Predictive characterization

Characterization and evaluation data are not always available for constructing trait-specific subsets of germplasm collections. The focused identification of germplasm strategy (FIGS) is a predictive characterization method that makes use of ecogeographical information on the sites from which the accessions were collected to determine with a high probability whether they harbour the traits of interest. FIGS has been used reliably to construct subsets of germplasm accessions. In wheat, for instance, Bhullar *et al.* (2009) successfully used FIGS to identify alleles for the powdery mildew resistance gene *Pm3* in a subset of 1 320 landraces that was created from a large genebank collection of 16 089 accessions.

[2] Further information at https://www.genesys-pgr.org/subsets.

TABLE 4.5
Number of subsets published by international and regional research centres, 2010 to 2019

Centre	Number of subsets published		
	2010–2014	2014–2019	2010–2019
AfricaRice	-	1	1
Bioversity	1	3	4
CIAT	2 035	11	2 046
CIMMYT	-	399	399
CIP	1	10	11
ICARDA	48	47	95
ICRAF	1	2	3
ICRISAT	3	3	6
IITA	-	5	5
ILRI	-	2	2
IRRI	-	14	14
WorldVeg	-	2	2
TOTAL	**2 089**	**499**	**2 588**

FIGS has also been used to create subsets of wheat germplasm for other traits, such as resistance to Russian wheat aphid (El Bouhssini *et al*., 2010), stem rust (Endresen *et al.*, 2012) and yellow or stripe rust (Bari *et al*., 2014). Similarly, FIGS facilitated the identification of sources of resistance to net blotch in barley (Endresen *et al*., 2011) and drought adaptation in broad bean (Khazaei *et al*., 2013). Haupt and Schmid (2020) applied FIGS to over 17 000 soybean accessions from the USDA Soybean Germplasm Collection and identified two diversity panels of 183 and 366 accessions, respectively, for abiotic stress adaptation in the crop.

4.4 Pre-breeding and germplasm enhancement

Pre-breeding is the introgression of novel traits from non-adapted germplasm into parental lines in order to generate intermediate materials that can subsequently be used in breeding improved crop varieties. It is a means both to introduce novel desirable traits and to broaden the genetic base of crops. In pre-breeding, the desirable traits are typically sourced from CWR, exotic materials and landraces. Pre-breeding requires collaboration between plant breeders and the genebank personnel who maintain the germplasm accessions.

More than 350 national research organizations from 76 countries implemented pre-breeding activities for 322 crop species, including fruit plants (20 percent), vegetables (18 percent), forages (12 percent), cereals (8 percent), herbs and spices (7 percent), pulses (7 percent), ornamentals (5 percent), and roots and tubers (5 percent), during the reporting period. Overall, wheat, maize, tomato, barley, sweet pepper, rice, potato, cowpea and common bean were the crops for which pre-breeding activities were most frequently conducted (Table 4.6).

The most frequent rationale for embarking on pre-breeding was the lack of the specific trait in current breeding materials (56 percent of all pre-breeding activities reported with rationales), followed by suboptimal genetic gains from breeding programmes (39 percent) and evidence of a narrow genetic base (32 percent) (Figure 4.1). Nearly 23 percent of all pre-breeding activities were driven by a combination of two or all three rationales.

Table 4.7 provides a non-exhaustive list of the key taxa/crops subjected to plant breeding, genetic enhancement and base-broadening efforts as reported by 67 countries.

The following subsections summarize the pre-breeding activities reported by countries.

Latin America and the Caribbean

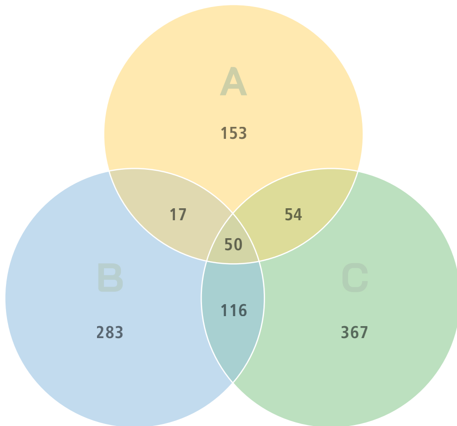
In Brazil, intensive pre-breeding work at Embrapa led to the release of various crop varieties for specific needs. The introgression of desirable traits from wild relatives of passion fruit resulted in the development of improved cultivars such as BRS Rubi do Cerrado (*Passiflora edulis*), BRS Pérola do Cerrado (*P. setacea*), BRS Céu do Cerrado (*P. incarnata* x *P. edulis*) and BRS Rosea

TABLE 4.6
Overview of the 18 crops that were the most frequent targets of pre-breeding activities between 2012 and 2019

Crop	Number of		
	Pre-breeding activities	Species	Countries
Wheat	106	5	34
Maize	87	3	37
Tomato/eggplant	67	6	37
Barley	56	3	28
Capsicum pepper	51	5	21
Rice	46	5	29
Potato	45	3	37
Cowpea	45	7	23
Beans	45	5	21
Prunus	35	9	14
Brassica	34	9	16
Soybean	33	2	19
Chickpea	29	2	14
Onions	28	6	14
Cucumber and cantaloupe	25	4	15
Pea	25	5	12
Cotton	25	6	11
Sorghum	25	3	21

Note: Based on 76 country reports.

FIGURE 4.1
Number of base-broadening activities undertaken during the reporting period according to three main rationales



Notes: A = evidence of narrow genetic base; B = poor gain in breeding programme; C = specific trait not available in current breeding materials. The distribution is based on 1 040 activities reported by 226 stakeholders in 64 countries.

Púrpura (*P. incarnata* x [*P. quadrifaria* x *P. setacea*]), BRS Sertão Forte (*P. cincinnata*) and BRS Mel do Cerrado (*P. alata*). Similarly, a wheat cultivar, BRS 404, which has significantly enhanced tolerance to drought and heat stress and is hence highly suitable for the Cerrado region of Brazil, was bred using an intermediate material developed using pre-breeding strategies.

Europe

Notable among several pre-breeding initiatives in Europe was the Public–Private Partnership for Pre-breeding in the Nordic region, which included projects such as Pre-breeding for Future Challenges in Nordic Apples (Finland, Norway and Sweden), Combining Knowledge from Field and from Laboratory for Pre-breeding in Barley II (Denmark, Finland, Iceland and Sweden) and Public–Private Partnership for Pre-breeding in Perennial Ryegrass (Denmark, Finland, Iceland, Lithuania and Norway). These projects aimed to deliver "easy-to-use" DNA markers to hasten the development of new crop cultivars.

The target traits for apple were resistance to fruit tree canker (caused by *Neonectria ditissima*) and storage rots (caused by *Neofabraea* spp. and *Penicillium expansum*). The project on barley involved screening spring barley germplasm for resistance to biotic stresses, including diseases such as scald, powdery mildew, leaf rust and *Fusarium* head blight. The identified lines were used to generate multiparent populations for use in the identification of genes for stress tolerance. The pre-breeding activities in perennial ryegrass involved the development of a broad-based population accompanied by high-density genotyping and multilocation phenotyping of the

TABLE 4.7
Main crops addressed in plant breeding, genetic enhancement and base-broadening efforts

Country	Main crops addressed
Argentina	Cereals, oilseeds, vegetables, fruit trees
Armenia	Wheat, tomato, triticale, peas, chickpea, basil, kohlrabi, clover, tall oat-grass, onion, garlic, vegetable marrow, vegetable soybean, summer squash
Azerbaijan	Legumes, apple, lemon, grapes, wheat, barley, cotton
Belarus	Cereals, legumes, oilseeds, vegetables, berry, nut crops, perennial cereals, leguminous forages
Botswana	*Jatropha*, cowpea, sorghum, tepary beans
Brazil	*Gossypium*, forages, fruits, pulses, black pepper, oilseeds, cassava, coffee, guarana, yerba mate, sugar cane, vegetables, *Araucaria*, *Hevea*
Cameroon	Cocoa
Colombia	Cocoa, fruit trees (gooseberry, cashew, soursop, guava), tubers (arracacha, yam, cassava, sweet potato), cereals (maize, oats, rice), vegetables (beans, peas, vine onions)
Costa Rica	Rice, oil palm, sugar cane, tomato, coffee, cocoa, maize, beans, grass, forage legumes
Cuba	*Phaseolus vulgaris, Capsicum annuum*
Denmark	Barley, wheat, oat, rye, oilseed rape, forage grasses, forage legumes, legumes, potato
Ecuador	Potato, maize, cocoa, cereals, Andean fruit trees
Egypt	Broad bean
El Salvador	Cocoa, sorghum
Eritrea	Wheat, barley, sorghum, pearl millet, maize, beans, rapeseed, pepper, onion
Ethiopia	Wheat, maize, barley, sorghum, lentil, chickpea, common bean/haricot bean, enset, avocado, mango, citrus, banana, papaya, noug, linseed, Ethiopian mustard, safflower, sunflower, tef
Finland	Barley, apple
France	Wheat, rapeseed, peas, maize, sunflower
Germany	Wheat, barley, lupin
Ghana	Maize, millet, rice, common bean, cowpea, groundnut, soyabean, cassava, cocoyam, frafra potato, sweet potato, yam, taro
Guatemala	Beans, maize
Guinea	Rice, groundnut, maize
Guyana	Sugar cane, cassava, sweet potato, watermelon, tomato, chili pepper, breadfruit, quinoa, onion, potato
Hungary	Soybean
India	Rice, wheat, chickpea, pigeonpea, green gram, black gram, lentil, brassica, barley, sesame
Indonesia	Rice, soybean, sweet potato, beans, coconut, ginger, cloves, nutmeg
Italy	Lucerne, field pea, white lupin, broad bean
Japan	Barley, maize, soybean, ryegrass, sugar cane
Jordan	Wheat, barley
Kenya	Pigeonpea, sorghum, finger millet, rice
Kyrgyzstan	Wheat, barley, apple, chickpea, alfalfa, soybean, plum, pear, cotton, garlic, maize, barley
Latvia	Barley
Lebanon	Wheat, barley, lentil, chickpea, broad bean
Madagascar	Rice, cassava, potato, beans, sweet potato, wheat, cocoa
Malaysia	Rice, cassava, watermelon, starfruit, rambutan
Mali	Sorghum, maize, millet
Mexico	Maize, chili
Mongolia	Wheat, barley, triticale, potato, tomato, pea, cabbage, sea buckthorn, strawberry, alfalfa

(Cont.)

Country	Main crops addressed
Namibia	Cowpea, sorghum, pearl millet, maize, groundnut, Bambara groundnut
Netherlands (Kingdom of the)	Tomato, potato, Brassica spp.
Nicaragua	Beans, sorghum, tomato, maize, cocoa, *Colocasia, Xanthosoma*
Niger	Voandzou, sesame, fonio, maize, groundnut, sweet potato, millet, sorghum, cowpea, rice, potato
Norway	Barley, wheat, oat, potato, timothy grass, red clover, white clover, rye grass, festuca grass, plum, strawberries, lucerne, apple, forages
Papua New Guinea	Sweet potato, coconut
Peru	Cotton, grapevine, maize, rice, beans, potato
Philippines	Rice, maize
Poland	Oat
Portugal	Cereals, grain legumes, fruits, vegetables, forages, medicinal and aromatic plants
Romania	Wheat, tomato, pepper
Serbia	Wheat, maize, forage (alfalfa, red clover), grain legumes (pea, broad bean, soybean)
South Africa	*Amaranthus*, hemp, medicinal cannabis, essential oil crops, cowpea, soybean
Sudan	Wheat, sorghum, pearl millet, cotton
Sweden	Wheat, triticale, barley, oat, oilseed rape, forage grasses, legumes, potato, *Salix*, turnip rape, perennial ryegrass, apple
Switzerland	Wheat, forage legumes and grasses, apple, soybean, grape, apricot, spelt, pear, aromatic and medicinal plants
Tajikistan	Wheat, barley, rye, oat, chickpea, bean, broad bean, lathyrus, lentil
Togo	Cassava, yam, rice, maize, coffee, cocoa, sorghum, sesame, groundnut, soybean
Trinidad and Tobago	*Lablab purpureus, Cucurbita moschata, Cajanus cajan, Theobroma cacao*
Tunisia	Wheat, barley, chickpea, broad bean, field bean, lentil
Türkiye	Wheat, barley, tobacco, sunflower, vegetables, fruit trees
Uganda	Sorghum, common bean, finger millet
United Kingdom	Cereals, sugar beet, oilseeds, grasses, potatoes, Brassicas, lettuce, onion, carrot
United Republic of Tanzania	Maize, tomato, finger millet, cowpea, common bean
Uruguay	Wheat, barley, rice, potato, sweet potato, tomato, deciduous fruit trees (citrus, peach, apple, pear and vine), Tinopiro (*Thinopyrum intermedium*), perennial sunflower (Silphium sp.).
Uzbekistan	Green gram, groundnut, safflower, sesame, Jerusalem artichoke, maize, tomato, sweet pepper, hot pepper, eggplant, sweet potato, pumpkin, vegetable marrow
Yemen	Wheat, maize, sorghum, peas
Zambia	Sunflower, castor, sesame, maize, sorghum, common bean, pigeonpea, groundnut, soybean, cotton, rice, cowpea, cassava, sweet potato, potato
Zimbabwe	Maize, soybean, groundnut, rice, sunflower, potato, cowpea, Bambara groundnut, beans, sorghum, pearl millet, finger millet

resulting population to train genomic selection models in order to obtain accurate prediction of phenotypes associated with wider adaptation.

In Poland, pre-breeding was conducted as part of genebank activities, particularly for widening the genetic base of winter oats through wide crosses with the wild species *Avena macrostachya*. In Italy, wild relatives were targeted with the aim of improving crops for tolerance to biotic and abiotic stresses. For example, the Research Centre for Cereal and Industrial Crops of the Council for Agricultural Research and Economics (CREA-CI) created a set of introgression lines in rice from the wild relative *Oryza rufipogon*.

Sub-Saharan Africa

In sub-Saharan Africa, pre-breeding activities were undertaken in Kenya under the auspices of the Crop Trust-funded Crop Wild Relatives Project. This involved various national and international partners, including ICRISAT, Rongo University, Kenya Agricultural and Livestock Research Organization, and Kisii and Maseno Universities. The pre-breeding activities targeted adaptation to drought in sorghum and tolerance to striga and blast in finger millet. They resulted in the development of several interspecific mapping populations and promising sorghum genotypes carrying superior traits for earliness, panicle characteristics and adaptation. They also led to the identification of promising lines using a farmer participatory approach.

The Ethiopian national programme used CWR from the Amazon rainforest to improve the adaptability of cocoa. Other breeding programmes attempted to integrate alleles from the wild into cultivated genetic backgrounds in chickpea and teff. In Cameroon, wild maize (teosintes from CIMMYT) and local varieties were used to transfer genes for high yields and adaptability into improved varieties. Pre-breeding activities in Mali were carried out for cowpea and sorghum in collaboration with the Cinzana Agricultural Research Station and CIRAD.

Asia

In the Philippines, traditional varieties and wild relatives of rice and maize were used to introgress desirable traits into breeding lines. In Lebanon, wild relatives of durum wheat were incorporated into breeding programmes for this crop, ultimately leading to the release of two new improved varieties. In Malaysia, the low-starch white rice varieties UKMRC-2 and UKMRC-8 were bred by crossing *Oryza sativa* and wild rice *O. rufipogon*.

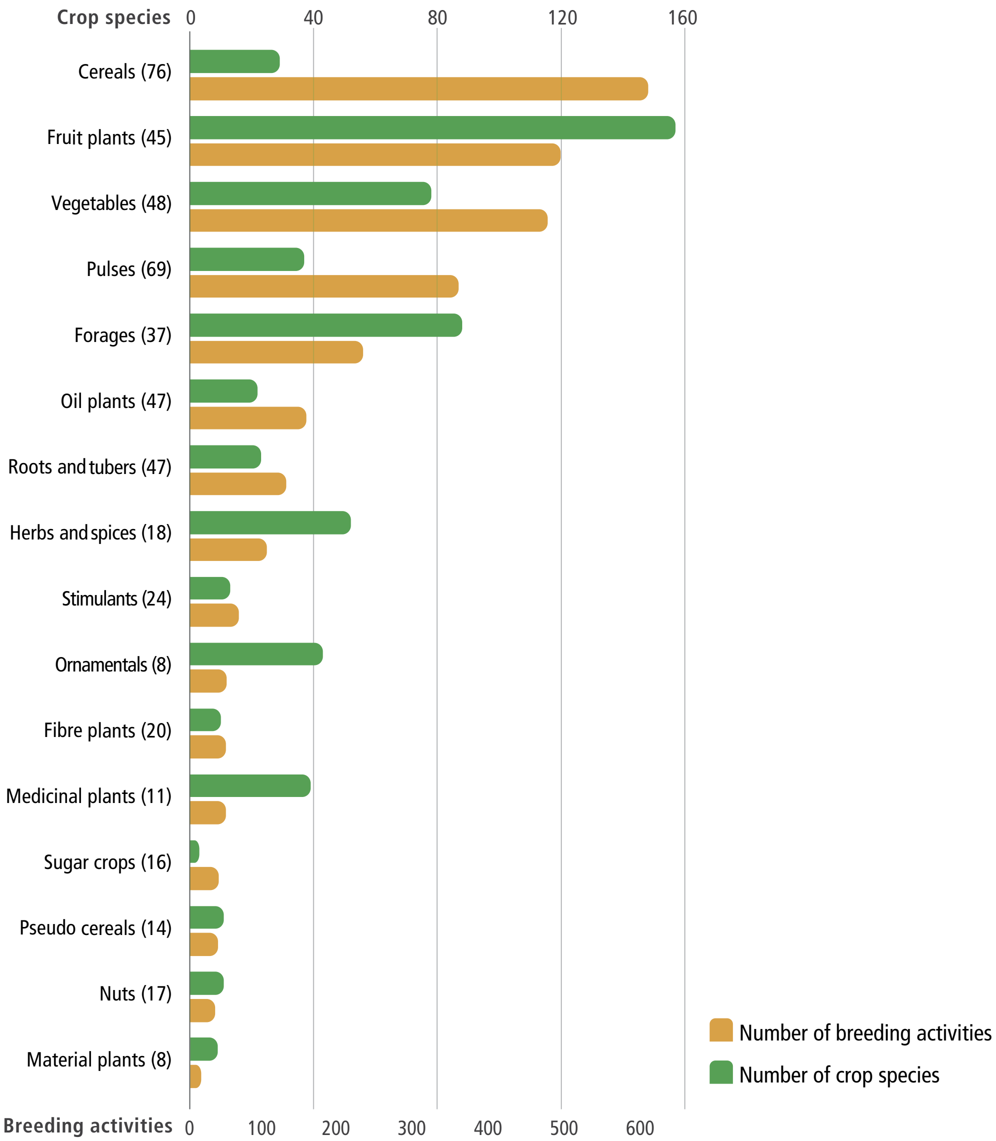
Inadequate human capacity was identified as a major constraint to pre-breeding, in particular pre-breeding involving the extensive use of wild relatives. For example, this limitation led to the discontinuation of some pre-breeding activities in Armenia that were reported in 2012 to be aiming to introduce new traits from wild wheat species and goat grass into improved wheat varieties.

4.5 Crop varietal development

With 602 breeding activities undertaken in 76 countries on 29 species, cereals were the crop group for which the largest number of crop improvement programmes were active over the reporting period (Figure 4.2). Fruit plants were the second most addressed group, with 487 breeding activities undertaken in 45 countries for 157 species. A total of 470 breeding programmes in 48 countries addressed the improvement of 78 species of vegetables. Significant efforts and resources were also invested in the genetic improvement of both pulses and forages.

The majority of the breeding and pre-breeding activities reported (3 463, or 77 percent) were supported through public funding. Public–private partnerships followed (601, or 13 percent). The remaining reported activities were funded by the private sector (456, or 10 percent). Most germplasm accessions used in plant breeding were sourced from national genebanks, followed by CGIAR genebanks and international and regional networks (Figure 4.3).

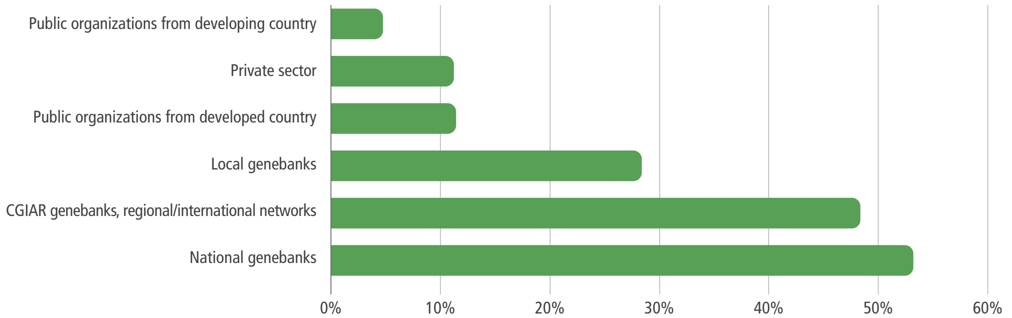
FIGURE 4.2
Number of breeding activities and number of crop species targeted, 2014–2019, by crop group



Notes: The number of countries reporting each crop group is shown in parenthesis after the name of the group.
Based on 87 country reports.

Note: Based on 76 country reports.

FIGURE 4.3
Germplasm sources for plant-breeding activities



Note: Based on 76 country reports

Overall, 50 997 improved crop varieties and 523 FV/LR – spanning 749 plant species – were registered and released in 82 countries between 2012 and 2019. The improved varieties belonged to 745 species and the FV/LR to 76 species. The crop group with the largest number of species for which varieties were released was ornamentals (173 species), followed by forages (151), fruit plants (132) and vegetables (85) (Table 4.8). Combined, cereals (27 species reported) and vegetables, accounted for more than half of all the released varieties – 29 percent and 28 percent, respectively. These groups were followed by oil plants and fruit plants (9 percent each). The two regions with the largest number of the registered and released varieties of cereals were Latin America and the Caribbean, and Europe, accounting for 39 percent and 33 percent, respectively. Brazil released the most cereal varieties (about 3 600), followed by Argentina, France and Mexico (more than 1 000 each). The region with the most releases of vegetable varieties was Europe (39 percent), with the Kingdom of the Netherlands having the largest number (more than 3 522 varieties from 32 crops). Latin America and the Caribbean accounted for 32 percent, with Brazil leading. Asian countries, including Türkiye and the Islamic Republic of Iran, accounted for 21 percent.

Registration and release of new fruit plant varieties was mostly reported in two regions, Europe (63 percent) and Latin America and the Caribbean (31 percent). Most of the released oil plant varieties were accounted for by Latin America and the Caribbean (44 percent), Northern America (19 percent) and Europe (17 percent). Forage variety releases were mainly reported in Europe (39 percent) and Asia (28 percent). Finally, a relatively large number of ornamental varieties were reported by countries in Latin America and the Caribbean.

Overall, these numbers were lower than those provided by seed associations, probably because of incomplete reporting by countries to FAO.

4.6 Advances that facilitate crop improvement

Ready access to a wide spectrum of well-characterized and documented PGRFA, including CWR and landraces that contain valuable heritable genetic variation, is of vital importance to efforts to breed the progressively superior new crop varieties that are needed to underwrite the food security and nutrition of the world's growing population, especially under worsening climate change scenarios. The significant advances that have occurred in genomics and phenotyping have greatly enhanced the scale and efficiency with which germplasm collections

TABLE 4.8

Number of species, improved varieties and farmers' varieties/landraces registered and released per region and crop group, 2012–2019

Crop group	Total (82 countries)			Northern Africa (4)			Sub-Saharan Africa (20)			Northern America (1)			Latin America and the Caribbean (15)			Asia (20)			Europe (20)			Oceania (2)		
	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV
Cereals	27	15 026	92	10	202	5	15	1 863	35	6	295	0	15	6 727	5	18	2 155	6	16	3 734	41	7	50	0
Vegetables	85	14 251	68	14	616	0	27	581	4				54	4 471	2	51	2 970	12	45	5 601	50	4	12	0
Oil plants	15	4 862	11	5	44	0	6	384	0	3	877	0	10	2 045	0	13	473	2	6	1 002	9	2	37	0
Fruit plants	132	4 544	231	7	30	0	7	27	0				85	1 485	0	39	103	11	64	2 792	220	18	107	0
Forages	151	3 174	7	8	106	0	29	193	1	15	212	0	88	766	0	42	378	3	57	1 484	3	18	35	0
Ornamentals	173	2 578	0				1	3	0				154	2 540	0	6	9	0	18	23	0	1	3	0
Pulses	32	2 177	20	5	46	0	18	400	4	4	122	0	13	362	0	18	539	4	15	669	12	7	39	0
Roots and tubers	15	1 669	77	2	108	0	12	188	34	1	248	0	8	322	34	5	161	2	2	631	7	1	7	0
Fibre plants	14	556	5	2	5	0	4	65	0	1	17	0	6	150	0	11	202	3	4	110	2	2	7	0
Sugar crops	4	542	0	2	29	0	1	20	0				2	111	0	3	102	0	2	270	0	1	10	0
Stimulants	9	526	0				5	54	0	1	2	0	8	420	0	4	24	0	1	25	0	1	1	0
Herbs and spices	45	488	6	1	37	0	13	34	0	2	7	0	21	166	0	23	133	3	17	110	3	1	1	0
Material plants	25	275	2				2	3	2				19	259	0	3	10	0	3	3	0			
Nuts	10	198	1				1	41	0				9	41	0	1	1	0	4	114	1	1	1	0
Medicinal plants	29	74	0				6	10	0				13	31	0	8	20	0	7	8	0	1	5	0
Pseudo-cereals	9	56	3				3	8	0	1	2	0	4	23	0	6	18	2	2	5	1			
Other	1	1	0																1	1	0			
Total	749	50 997	523	52	1 223	5	149	3 874	80	33	1 782	0	493	19 919	41	245	7 298	48	259	16 582	349	65	315	0

Notes: CV = improved varieties. FV = farmers' varieties/landraces. The numbers of reporting countries are shown in parenthesis after the region names.

are characterized and otherwise used for trait discovery and crop varietal development. Some of the more commonly used methods that have the potential to enhance the scale and efficiency of conserving, characterizing, evaluating and exploiting the inherent hereditary potentials of PGRFA are discussed in the following subsections.

4.6.1 Genomics-guided development of broad-base populations

The advanced backcross QTL method (AB-QTL) combines the identification of a quantitative trait locus (QTL) with its introgression into a breeding material (Tanksley and Nelson, 1996). The AB-QTL method has been used for the genetic dissection of complex traits and the development of superior lines in several crops, including tomato (Fulop *et al.*, 2016), rice (Nagata *et al.*, 2015, Xia *et al*., 2017), wheat (Naz *et al*., 2019; Sayed *et al*., 2021), barley (Bauer *et al*., 2009; Mora *et al.*, 2016), common bean (Blair and Izquierdo, 2012), groundnut (Alyr *et al*., 2020; Essandoh *et al*., 2022) and pigeonpea (Saxena *et al*., 2020).

The creation of genetic stocks that serve as the complete library of the respective donor genome (CWR or FV/LR) is enabled by methodologies that track the inheritance of specific genomic regions in the recipient background. Chromosome segment substitution lines (CSSLs), for instance, constitute genetic stocks that harbour the entire genome of the exotic, i.e. donor, accession in the genetic background of the recipient. The development and analysis of CSSLs have enabled the genetic dissection of complex traits in several crops, including rice, wheat, maize, pearl millet, barley, soybean, groundnut, pea, rapeseed and cabbage (see Balakrishnan *et al*., 2020).

4.6.2 Multiparent populations

The development of multiparent populations whereby the genomes of multiple founders are mixed and recombined to generate populations with high genetic diversity, has become an efficient means of leveraging broad genetic variation for crop improvement and for elucidating the heredity of complex traits. The two most common designs are nested association mapping (NAM) and multiparent advanced generation intercross (MAGIC) (Varshney *et al*., 2021b; Bohra *et al.*, 2020).

The NAM design was originally proposed in maize as a community mapping resource with enhanced statistical power. The maize NAM design was based on the crossing of B73, an inbred line used as parent in several maize hybrids, with 25 diverse inbred lines, thus generating a set of 5 000 recombinant inbred lines corresponding to 25 "interconnected" populations (Yu *et al*., 2008). The enormous potential of NAM design for understanding complex trait architectures has been demonstrated in maize by genetic analysis of various traits, including flowering time, southern leaf blight and northern leaf blight, leaf architecture, kernel composition and drought tolerance. In recent years, the NAM design has been further extended to several other crops for high-resolution genetic dissection of a variety of agriculturally important traits, including the following: leaf rust resistance, flowering time, salinity tolerance, net blotch and yield-related traits in barley; days to heading, recombination events and segregation distortion in rice; adaptive traits in sorghum; yield and agronomic traits in soybean and common bean; resistance to rust and powdery mildew in wheat; and seed and pod weights in groundnut (Gireesh *et al.*, 2021).

Inspired by the collaborative cross mouse panel derived from eight founder parents,[3] MAGIC is another, though more complex, multiparent population design used in plants, which incorporates broad genetic diversity in the resulting mapping populations. A MAGIC design involving 19 accessions was first used in Arabidopsis (Scarcelli *et al.*, 2007; Kover *et al.*, 2009) and, with adjustments to minimize crossing, later adopted in several crop plants, including maize, rice, barley, wheat, sorghum, tomato, Chinese mustard, cotton, cowpea and broad bean (Scott *et al*., 2020). More recently, Novakazi

[3] Further information at https://csbio.unc.edu/CCstatus/CCGenomes

et al. (2020) developed four MAGIC populations in barley by using 17 founder parents that included cultivars, breeding lines and FV/LR. The genome-wide association studies on the MAGIC populations provided QTLs, candidate genes and haplotypes for improving resistance to important diseases, such as powdery mildew (Novakazi *et al.*, 2020) and scald (Hautsalo *et al.*, 2021).

Genomic selection has become a promising method for improving the rate of genetic gain in plant breeding populations. The acquisition of large-scale genotype and phenotype information on germplasm sets and breeding populations helps in the development of genomic selection prediction models to quickly and accurately determine the genetic worth of PGRFA for use in breeding. Based on genome-wide marker information, genomic selection has helped to optimize selection strategies for choosing worthy genotypes in the absence of phenotypic information. For example, by generating GBS data on 962 sorghum accessions, Yu *et al.* (2016) demonstrated the efficacy of genomic prediction as a novel and cost-effective strategy for mining traits from genebank accessions CIMMYT's Seeds of Discovery project[4] used genomic predictions to help increase the frequency of favourable alleles detected in CWR populations and to shorten the length of breeding cycles. In the reporting period, 51 countries (about 76 percent of those reporting on this topic) documented the use of genomics for pre-breeding.

4.6.3 Modern phenotyping platforms

Rapid advances in the development of non-invasive and digital technologies have facilitated remarkable increases in the throughput and accuracy of plant phenotyping over the last decade. Advances in sensor and imaging techniques operating at different scales and levels (leaf, canopy and airborne) have enabled the assaying of large population sizes and the concomitant generation of large amounts of data, thereby relieving the so-called "phenotyping bottleneck" that has been a major hindrance to plant breeding programmes (Varshney *et al.*, 2021c). The constant refinements of plant phenotyping platforms for mobility, affordability, throughput, accuracy, scalability, data storage and analytics facilitate efforts to bridge the gap between the genome and its phenotypic manifestation (Zhu *et al.*, 2021).

The International Plant Phenotyping Network[5] (IPPN) is comprised of six regional[6] and seven national[7] partners and aims to increase the visibility and impact of plant phenotyping by making relevant information available via a web-based platform. The goal of IPPN is to enable cooperation among stakeholders from academia, industry, government and the general public.

4.6.4 Genome editing

Genome editing, also known as genome engineering or gene editing, is the term used for a set of relatively recently described molecular techniques that are used to induce site-specific mutations in living organisms. This is achieved through the insertion, deletion, modification or replacement of DNA in the genome of the organism. Zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs) and, more recently, clustered regularly interspaced short palindromic repeats CRISPR/Cas9 are the three most commonly used genome editing techniques. Emmanuelle Charpentier (Max Planck Unit for the Science of Pathogens, Berlin, Germany) and Jennifer Doudna (University of California, Berkeley, United States) jointly won the Nobel Prize for Chemistry in 2020 in recognition of their invention of CRISPR/Cas9.

4 Further information athttps://seedsofdiscovery.org

5 See https://www.plant-phenotyping.org

6 See https://emphasis.plant-phenotyping.eu; https://eppn2020.plant-phenotyping.eu; https://www.plantphenotyping.org; http://nordicphenotyping.org; Latin American Plant Phenomics Network (LatPPN); https://www.wheatinitiative.org/wheat-initiative

7 See http://www.appn.at/about; https://www.plantphenomics.org.au; China Plant Phenotyping Network (CPPN); https://dppn.plant-phenotyping-network.de; http://www.phen-italy.it/index.php; https://www6.dijon.inrae.fr/umragroecologie_eng/Research-Programs/Investissement-Avenir/PHENOME; https://www.phenomuk.net

The potential use of gene editing to improve disease resistance has been demonstrated for rice (brown plant hopper, rice tungro spherical virus, blast, bacterial blight), wheat (rust, powdery mildew), maize (lethal necrosis), banana (Fusarium wilt, banana streak virus), tomato (Fusarium wilt, powdery mildew, bacterial speck, *Botrytis cinerea*, *Pseudomonas syringae, Phytophthora capsici, Xanthomona*s spp.), potato (late blight, potato virus Y), grape (powdery mildew, citrus canker, Botrytis cinerea) and apple (fire blight) (Macovei *et al*., 2018; Luo *et al*., 2019; Ortigosa *et al*., 2019; Pompili *et al*., 2020; Wan *et al*., 2020; Biswal *et al*., 2022; Nourozi *et al*., 2024). The potential use of the techniques for engineering abiotic stress tolerance has also been demonstrated, in particular for drought tolerance in rice and maize, salinity tolerance in rice, and semi-draft trait for lodging resistance in banana. The examples of the traits they have been used to improve include:

- rice: increased amylose and carotenoids, lower cadmium uptake;
- wheat: lower gluten;
- maize: reduced starch, reduced phytic acid;
- potato: reduced starch;
- groundnut: increased oleic acid content;
- tomato: increased anthocyanin levels;
- sorghum: reduced kafirins; and
- soybean: altered oil levels.

Gene editing has also been applied to so-called orphan crops such as cassava for improved disease resistance (African cassava mosaic virus, bacterial blight, cassava brown streak) and quality traits (waxy starch, cyanide free) (Karavolias *et al.,* 2021; Pixley *et al*., 2022; Zaidi *et al*., 2020).

Table 4.9 presents descriptions of the application of plant biotechnologies in countries' breeding programmes.

4.7 Diversification of crop production systems

High-input crop production systems, which are based on a few varieties of a small number of major crops, are prevalent in many parts of the world – contributing to the vulnerability of food systems to shocks and their inability to provide enough nutrients to those who depend on them. These shortcomings persist despite the availability of many other crops and varieties, including so-called neglected and underutilized species and FV/LR, that could easily be used to enhance the intraspecific and interspecific diversity of crop systems and would provide better resistance to biotic and abiotic stressors, and better nutrition outcomes (FAO, 2011). Constraints to diversification through the routine introduction of new crops and varieties include the absence of suitable varieties for prevailing dietary preferences, lack of information on their existence or their availability, weak value chains and markets, and suboptimal enabling environments.

4.7.1 Increasing diversity in crop production systems

Almost 300 stakeholders in 73 countries are reported to have carried out programmes, projects or activities aimed at increasing diversity in crop production systems during the reporting period. These initiatives were typically collaborative efforts undertaken jointly by various organizations and involving farmers. They also typically included the assessment and/or monitoring of interspecific and intraspecific diversity in production systems.

In Sweden, for instance, a countrywide network of agricultural advisory services was instrumental in making farmers aware of the continuous development of new crop varieties, including through the provision of information on variety testing.[8] In Ethiopia, drought-tolerant durum wheat varieties developed from farmers' varieties were released as a means of enhancing on-farm diversity and, hence, increasing resilience. The African Orphan Crops Consortium aimed to develop next-generation genomics resources for genetic improvement to inject new, improved, adapted and productive varieties into cropping systems.

[8] Further information at https://uniseco-project.eu/case-study/sweden

TABLE 4.9
Extent of application of plant biotechnology in breeding programmes, by country

Country	Response
Armenia	Biotechnological techniques have gradually evolved, and application of tissue culture and micropropagation in crop improvement is reported for vegetable crops (peppers, tomatoes and cucumber).
Azerbaijan	The use of biotechnology in breeding activities has become widespread in recent years. This is one of the main scientific focus areas of the Department of Biotechnology at the Genetic Resources Institute. In recent years, relevant departments have also been established at the Research Institute of Vegetable Growing and the Research Institute of Fruits and Tea Growing, and these have been equipped with modern equipment. However, the use of biotechnology methods in these institutes is more focused on the rapid multiplication of existing germplasm. The plan is for the departments to contribute to selection work.
Belarus	Plant biotechnology methods were applied in breeding within the framework of the 2016–2020 state research programme "Biotechnologies" and its subprogramme "Structural and Functional Genomics".
Botswana	Molecular characterization has been carried out for *Sorghum bicolor* and *Jatropha curcas* accessions.
Brazil	Biotechnology techniques have been used for the identification, selection and introgression of new genes. During the reporting period, 56 pre-breeding programmes (28 percent) mentioned that they used molecular markers to estimate genetic diversity. This approach was adopted in 32 crops (passion fruit, groundnut, potato, maize, banana, cassava, melon, aroeirinha, plum, forage palm, camu camu, tucumã, coffee, pepper, black pepper, beans, sugar cane, papaya, Heliconia, Spondias, tomato, coconut, rice, Paspalum, soybean, cotton, sorghum, apple, açaí, sesame, castor, and citrus and the like). Embrapa's project portfolio currently includes genomic editing projects on rice, soybean, maize, wheat, sugar cane, apples, grapes and coffee, among other crops.
Brazil	Gossypium, forages, fruits, pulses, black pepper, oilseeds, cassava, coffee, guarana, yerba mate, sugar cane, vegetables, Araucaria, Hevea
Cameroon	Because of a lack of capacity, especially human capacity, in this field, the use of plant biotechnology by breeding programmes has been slow to produce results. An upgrade of the technical platform and human capacities is needed. Use of plant biotechnology would greatly shorten selection times compared to the traditional method.
Canada	Research on the genomics-based characterization of Plant Genetic Resources Canada germplasm collections has involved several research projects associated with collections of wheat, oat, barley, flax, yellow mustard, Jerusalem artichoke and four native grass species. These research efforts have generated many innovative characterization tools, advanced knowledge of crop genetic diversity and the molecular make-up of gene pools, and contributed to germplasm conservation and utilization. Marker-assisted selection (MAS) and genomic selection have been applied in several programmes, including flax.
Colombia	Many biotechnological tools are used in different institutions. There are many research and pre-breeding projects that involve the use of molecular markers, identification and isolation of genes, molecular mapping, genetic transformation and gene editing. However, during the reporting period, the use of these tools in plant-breeding programmes, as measured in terms of successful development of cultivars registered in the competent authority's national registry of varieties, was very low.
Costa Rica	Biotechnology is playing an increasingly important role in genetic improvement and seed production activities, including seed multiplication, health diagnosis, conservation, characterization and gene editing, with greater progress in some areas than others.
Cuba	The Centre for Genetic Engineering and Biotechnology conducts research aimed at obtaining genetically modified organisms and introducing them into agricultural production as an alternative. For each variety or line obtained, consideration is given to its agronomic attributes, its potential to increase agricultural yield, its adaptation to limiting edaphoclimatic factors and the technology involved in its use – all with the overall aim of increasing the country's food productivity. The work is done mainly on soybeans and maize.
Eritrea	Genetic diversity has been assessed through molecular markers for sorghum striga resistance.
Ethiopia	Use of biotechnology includes: • molecular phenology and protoplast fusion; • tissue culture and double haploid breeding; • characterization of indigenous accessions of various crops using isozyme markers; • haplotype analysis of resistance genes using linked markers; • identification of new resistance sources from landraces; and • genetic engineering (transformation).
Finland	Domestic plant breeding has a strong market share, and Finland is not dependent on foreign breeding programmes for the major field crops. It relies on the regional genebank NordGen, which is actively involved in the Nordic Public–Private Partnership for Pre-breeding and thus provides germplasm and a platform for genetic enhancement for some major field crops. The local breeding programme occasionally utilizes genetic material for widening the genetic base, mainly for improving resistance traits. Among horticultural crops, particularly strawberry, pre-breeding has been started by utilizing the genetic resources of the parental species to reconstruct hybrid species for integrating new variation into breeding programmes. To enhance breeding, genomic tools and in vitro cultivation techniques are used in field-crop breeding. The definition of breeding goals for field crops in Finland involves regular active communication with the various actors in the food chain.

Country	Response
France	The use of molecular markers is widespread in preselection or selection programmes (75 percent), in most cases supplemented by phenotypic studies in the context of work on association genetics.
Guatemala	The number of molecular techniques (microsatellites, simple sequence repeats [SSR], sequence characterized amplified region [SCAR], insertion–deletion [INDEL], semi-thermal asymmetric reverse PCR [STARP]) used has been increased to assist in the genetic improvement of beans. They have also been applied to maize families with high protein quality (quality protein maize or QPM) to identify the presence of a gene (Opaque-2). The germplasm used in the studies came from the breeding programmes of the Institute of Agriculture of Science and Technology (ICTA) and was stored in the ICTA germplasm bank. The ICTA biotechnology laboratory works with the maize and bean improvement programmes on assisted breeding with molecular markers. This is a new activity that was not previously reported.
Guinea	Guinea does not have the laboratories to carry out selection assisted by molecular markers.
Indonesia	Biotechnology has been used in breeding since 1997 for various commodities. High-yielding varieties have been produced through biotechnological approaches, especially through MAS (rice and maize) and mutation breeding (sorghum, soybeans and rice). The use of genetic engineering techniques has resulted in transgenic sugarcane and potato varieties. The transgenic potato variety is in the process of being released.
Italy	The use of biotechnologies in agriculture in the last decade has been affected by a ban on the commercialization of biotech varieties and field experimental trials on them. The situation has worsened since the 2018 judgement of Court of Justice of the European Union on new breeding techniques. At the research level, the Italian flagship project BIOTECH, funded by the Ministry of Agriculture, has received a substantial boost. Under this project, 13 subprojects are trying to apply genome editing and cis-genesis to several agricultural crops (wheat, apple tree, citrus and tomato), addressing several important traits controlling quality, yield and resistance to biotic and tolerance to abiotic stresses. At CREA CI some interesting quantitative trait loci that can potentially be used by breeders have been identified through genome-wide association studies.
Japan	Public acceptance of genetically modified crops has not progressed in Japan, and no genetically modified field crop varieties have been put into domestic crop production. In major crops, selective breeding using DNA markers derived from genomic information is widespread.
Jordan	The use of biotechnology in plant breeding is still at an early stage, but its use is increasing.
Kenya	Kenya has made advances in the use of biotechnology in breeding. Genetically modified Bt maize and Bt cotton are currently being tested by the Kenya Agricultural and Livestock Research Organization, the Kenya Plant Health Inspectorate Service and other partners. Conditional approval has been given by the National Biosafety Authority for the commercialization of Bt cotton. Similarly, conditional approval has been given for Bt maize, but trials had not been conducted by the end of the reporting period.
Lebanon	Plant biotechnology is not yet used in breeding programmes in Lebanon.
Madagascar	Application of plant biotechnology still weak.
Malaysia	Research has been done on transgenic papaya, delayed ripening in papaya through molecular manipulation, and the development of hermaphrodite papaya through vegetative propagation.
Mali	Biotechnology is used on sorghum and cowpea.
Mexico	Biotechnology for plant genetic improvement is little used in the generation of new varieties by public institutions, which mainly use classical genetic improvement.
Namibia	The Ministry of Agriculture Water and Land Reform has a biotechnology laboratory and has just started finger printing newly improved crop varieties. The University of Namibia, through the Department of Biology in the Faculty of Science, also conducts biotechnology research, emphasizing genetic characterization and MAS in pearl millet, sorghum and leguminous crops.
Nepal	Application of biotechnology in breeding programmes is very poor. The major work done using biotechnology is to assess genetic diversity
Niger	The use of plant biotechnology by breeding programmes is in its early stages. Notably there are fairly well-equipped laboratories run by highly competent researchers. There is a good development of in vitro culture for the acceleration of certain phases of selection.
Nigeria	Plant biotechnology is used to a moderate degree.
Peru	The application of plant biotechnology in plant breeding has been relatively limited. Peru had a moratorium on the entry of transgenic crops from 2011 to 2021, which probably also limited the participation of the private sector in genetic improvement through biotechnology. Although research on the use of biotechnology in genetic improvement is not prohibited, the public sector has made relatively few efforts to apply it. Plant breeding programmes use conventional techniques for the most part. However, more human resources capable of applying biotechnology for genetic improvement are required.

(Cont.)

Country	Response
Philippines	Plant biotechnology is employed in crop improvement to address specific breeding objectives in *Zea mays, Oryza sativa, Solanum melongena, Musa textilis* and *Mangifera indica*.
Poland	Molecular markers linked to disease resistance are being used for selection in breeding programmes.
Republic of Moldova	Several institutes report the use of plant tissue culture technique in the breeding of tomato, wheat, triticale, barley, potatoes, grapes. Progress is limited.
Serbia	Biotechnology contributes to every breeding programme at the Institute of Field and Vegetable Crops Novi Sad, including pre-breeding, MAS (lines with desired traits) and even estimation of general and specific combining abilities.
Sweden	Plant biotechnology is commonly used, in particular MAS, genomic selection and haploid techniques.
Trinidad and Tobago	The Research Division has played an important role in the testing, evaluation and breeding of crop plants for the benefit of farmers. The genetic improvement and selection programme has included the selection of appropriate root crop, *Cocos nucifera* and *Cucurbita moschata* varieties for value addition and export. The Cocoa Research Section evaluated Theobroma cocoa varieties for tolerance to witches' broom and black pod diseases and for flavour profiles, cocoa butter fat content and productivity characteristics. Because of staff limitations and financial resources, the Research Division currently has limited technical capacity to engage in plant breeding and genetic enhancement work.
Tunisia	The degree of involvement of biotechnology in breeding programmes remains low and is limited to a few crops, notably cereals and legumes and vegetable crops. The main cereal crops affected by genetic improvement are durum wheat, bread wheat and barley. For food legumes, the main crops are broad beans, chickpeas and lentils. These programmes aim to develop varieties that are more efficient, more adapted and more tolerant to various biotic and abiotic constraints. This is done by using classic selection methods (pedigree selection and bulk selection) and by integrating the use of molecular tools such as SCAR markers, diagnostic markers and microsatellite markers for MAS.
United Kingdom	The country is a signatory of the International Treaty on Plant Genetic Resources for Food and Agriculture, and so its government-funded genebanks support distribution of material through the Multilateral System of the of the International Treaty on Plant Genetic Resources for Food and Agriculture. The Germplasm Resource Unit at the John Innes Centre recently entered into collaboration with the Chinese Academy of Agricultural Sciences to obtain resequencing information for around 700 accessions from the John Innes Pisum collection. Together they aim to generate a world-leading resource for gene discovery and forward breeding in pea. To represent the best possible diversity snapshot of the collection, 500 accessions from the John Innes Pisum germplasm collection were chosen using the core-collection novel analysis. An additional 114 accessions were included following a request from the Pulse Crop Genetic Improvement Network (PCGIN) management team. The John Innes Centre also contributes internationally to the work done by the EVA European Wheat and Barley Evaluation Network. At national level, it is involved in the PCGIN. The United Kingdom Vegetable Genebank (UKVGB) works closely with the Vegetable Genetic Improvement Network, and its material is also being used by the Oilseed Rape Genetic Improvement Network. Pre-breeding activities that have been facilitated through the aforementioned genetic improvement networks are central to activities of both the John Innes Centre and the UKVGB.
United Republic of Tanzania	Plant biotechnology is gaining more attention, but more technical and financial support may be required to enhance its use.
Uruguay	The following examples of the application of biotechnology in breeding programmes stand out: transgenesis, adaptation for resistance to drought in soybean; development of haploids in potato; speed breeding in wheat.
Uzbekistan	Biotechnology methods are widely used in plant breeding, especially in the propagation of the resulting hybrids.
Yemen	Because of poor physical and technical capabilities the use of biotechnology is still weak.
Zambia	The extent of application of plant biotechnology in breeding programmes has been very low in the private sector and virtually non-existent in the public sector.
Zimbabwe	Current projects in agricultural biotechnology are mainly carried out at universities and public research institutes and are aimed at improving disease, herbicide, drought and insect resistance and plant propagation. Zimbabwe is involved in industrial biotechnology at a low level through research and use of the country's biological resources as sources of potential industrial enzymes. For example, the Harare Institute of Technology is currently using tissue culture techniques to develop oyster mushroom for commercial purposes. Biotechnology is also being used in food processing, where biotechnological research is focused on microbiology and biochemical processes and the use of starter cultures during fermentation of traditional foods such as Mahewu, a non-alcoholic beverage made from malt and sour milk.

The Soils, Food and Healthy Communities[9] project assisted smallholder farmers in Malawi to use the "doubled-up" legume technology as an intercrop or rotation with the main cash crop, maize. This exploited the complementary growth habits of two different legume crops, pigeonpea and groundnut. The outcomes were improved nutrition, especially for children, increased soil fertility and land productivity, and reduced incidence of pests and diseases. The project

9 Further information at https://soilandfood.org

also led to the establishment of agriculture and nutrition discussion groups as a platform for the informal exchange of agricultural knowledge and resources. The ecological principles that were validated through the project were later adopted and scaled up by the Government of Malawi's agricultural extension system and by the Feed the Future[10] and Africa RISING[11] initiatives, both funded by the United States Agency for International Development.

Intercropping was used to increase crop diversity in agricultural systems in a number of countries. In Italy, the Research Centre for Zootechnics and Aquaculture of the Council for Agricultural Research and Economics (CREA-ZA) selected the field pea cultivar (Pifor) for this purpose. Intercropping sorghum and pearl millet with grain legumes was promoted in Eritrea. The strip cropping of arable and vegetable crops in the Kingdom of the Netherlands provided yields comparable with those of monocultures while also reducing pest and disease pressures and increasing biodiversity.

Indigenous vitamin- and mineral-rich leafy African vegetables, such as amaranth (*Amaranthus* spp.), cleome (*Cleome gynandra*), African nightshades (*Solanum* spp.) and cowpea (*Vigna unguiculata*), were reintroduced into cultivation and diets through collaborative initiatives involving research institutes, including Bioversity International, farmer associations and women's empowerment groups in Botswana, Cameroon, Kenya, Senegal and Zimbabwe. Improved cultivation, practised in combination with adequate seed systems, awareness raising and marketing campaigns, led to an increase in dietary diversity, farming system adaptability and household incomes, with women being the major beneficiaries. Efforts to promote the orange-fleshed sweet potato are described in Box 4.1.

There were several instances of the public sector collaborating with NGOs to promote on-farm diversity, including the Garden of Moldova initiative in the Republic of Moldova, which promoted various agroecological practices and crop rotation. In Mongolia, where wheat monoculture is dominant and occupies over 85 percent of the total cultivated area, the new pea variety Bayalag was widely cultivated for animal feed as well as for green manure for soil improvement in wheat rotation systems in the country's central and eastern cropping zones. Well-adapted extra-early varieties of soybean and maize were also introduced into Mongolia's cropping systems. In Malaysia, the government focused on a few priority crops such as coconut, pineapple, durian and maize, both diversifying agriculture and helping to generate more income for farmers.

In Asia, the Southeast Asia Regional Initiatives for Community Empowerment (SEARICE)[12] initiated several programmes that aimed to increase on-farm diversity and inform policy development in five countries (Bhutan, the Lao People's Democratic Republic, the Philippines, Thailand and Viet Nam). The cultural practices that were promoted included crop mixtures, crop rotations, intercropping and cover crops. The programmes[13] included Democratizing Agricultural Research and Extension (2011), Putting Lessons into Practice: Scaling-up People's Biodiversity Management for Food Security (2012), Building Resilient Community Managed Seed Systems Towards Climate Change Adaptation (2013), Sowing Diversity = Harvesting Security (2014), Policy Research and Awareness Improvement on Seeds (2017) and Rights to Seeds (2018).

4.7.2 Introduction of new crops, reintroduction of crops and domestication of wild species

Several instances of the successful introduction of new crop species into countries' cropping systems have been documented in recent years. During the reporting period, 346 crops (Table 4.10) were newly introduced from abroad in 63 countries

[10] Further information at https://www.feedthefuture.gov
[11] Further information at https://africa-rising.net/
[12] Further information at https://www.searice.org.ph
[13] Further information at https://www.searice.org.ph/past-projects

Box 4.1

Promotion of orange-fleshed sweet potato in Africa

Orange-fleshed sweet potato (OFSP), a biofortified crop variety that was developed to combat vitamin A deficiency among children and women, a significant public-health concern in sub-Saharan Africa, has been introduced into the cropping systems of many African countries (Girard *et al.*, 2021). Programmes promoting OFSP have included the sweet potato for profit and health initiative (2010 to 2014), which was followed by an expanded dissemination effort in the period from 2015 to mid-2019. OFSP reached approximately 10 million African households by 2020 and helped both to address malnutrition and to increase economic returns to families.[a] Other projects that sought to promote OFSP were Mama SASHA in Kenya, VISTA in the United Republic of Tanzania, Nutritious Diets for Niassa, in Mozambique, and Quality Diets for Better Health in Sidama and Gedeo zones, Southern Nations, Nationalities, and Peoples' Region, Ethiopia (Girard *et al.*, 2021). To address consumer preference, the International Potato Center started a breeding programme, Breed in Africa for Africa, to develop OFSP varieties with better taste and adaptation. Between 2009 and 2021, more than 100 OFSP varieties were released by 16 countries in the region (Girard *et al.*, 2021).

Source: Girard, AW., Brouwer, A., Faerber, E.G., Frederick, K. & Low, J.W. 2021. Orange-fleshed sweetpotato: strategies and lessons learned for achieving food security and health at scale in Sub-Saharan Africa. *Open Agriculture*, 6: 511–536. https://doi.org/10.1515/opag-2021-0034

[a] Further information at https://www.sweetpotatoknowledge.org/topics/sweetpotato-for-profit-and-health-initiative-sphi

TABLE 4.10

Reported number of crop species introduced from abroad and reintroduced from a genebank collection, and number of wild species newly domesticated, by crop group, 2012–2019

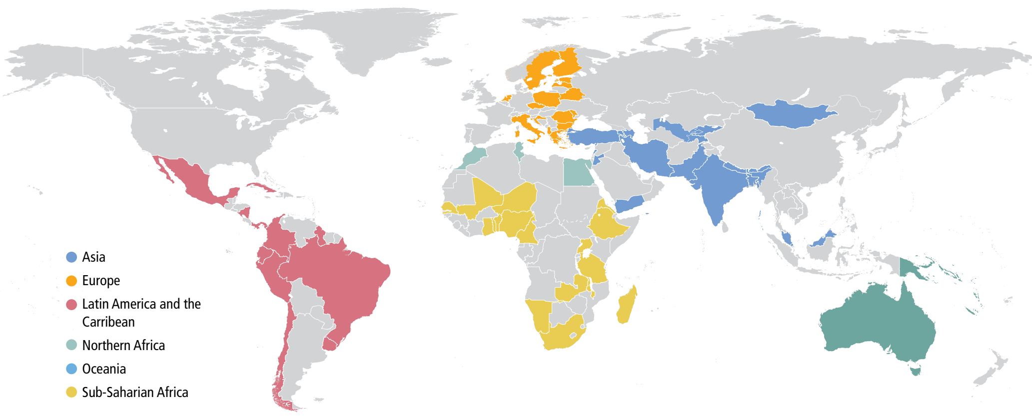
Crop group	Number of		
	Newly introduced crops	Reintroduced crops	Wild species domesticated
Fruit plants	88	19	18
Vegetables	60	20	10
Pulses	29	19	6
Herbs and spices	21	5	20
Cereals	25	15	3
Forages	25	9	7
Medicinal plants	21	1	17
Ornamentals	25		7
Oil plants	11	6	1
Material plants	10		1
Roots and tubers	5	5	1
Stimulants	6	2	3
Fibre plants	7		1
Nuts	7		1
Pseudo-cereals	4	2	
Sugar crops	2	1	1
Total	346	104	97

Note: Data provided by 71 countries.

(Figure 4.4), 104 crops were reintroduced in 30 countries using seeds sourced from genebanks (Figure 4.5), and 97 wild species were introduced into cultivation in 18 countries (Figure 4.6).

Overall, the crop group that accounted for the largest number of newly introduced species was fruit plants (25 percent), followed by vegetables (17 percent), pulses (8 percent), cereals and forages (7 percent each). The largest number of newly introduced crops were from the genera Prunus and Brassica. Prunus crops included several interspecific hybrids, while Brassica crops included cabbage, broccoli, cauliflower, kale, Brussels sprouts, kohlrabi, pak choi and rape. Quinoa was the crop introduced into cultivation in the largest number of countries, five countries in Asia, five in Europe, three each in Northern and Western Africa, and two in Latin America and the Caribbean (Guyana and Nicaragua). Other newly introduced crops included northern highbush blueberry *(Vaccinium corymbosum)* and buckwheat (*Fagopyrum esculentum*) in Latin America, *Ziziphus jojoba* in some areas of Greece and Jordan, and *Averrhoa carambola* in the Sindh province of Pakistan and the surrounding area of Islamabad. Newly introduced crops in Uzbekistan

FIGURE 4.4
Countries reporting newly introduced crops



Notes: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 63 country reports.

included pawpaw and kiwi.

In Eritrea, varieties of date palm, Irish potato and green gram were introduced, the cultivation of emmer wheat was expanded and sweet potato was reintroduced. In Kenya, 200 sorghum and finger-millet accessions were introduced into cultivation, and nearly 2 million seedlings of underutilized nutrient-dense fruit species, including guava, jackfruit, pomegranate, custard apple, loquat, gooseberry, blackberry, raspberry, tree tomato, tamarind and java plum, were distributed to farmers.

Several new crop species, such as triticale, soybean, pea, maize, camelina, sweet sorghum, flax, cultivated strawberry, leafy vegetable species, apple and blue honeysuckle berry, were successfully introduced into various areas of Mongolia. In addition, the area of cultivation of new berry varieties obtained from Canada, Japan and the Russian Federation increased in various parts of the country's cropping zones.

Introductions of new and "forgotten" crops helped to reduce reliance on food imports. The "Better products, new crops" initiative at Wageningen University and Research, which was implemented in collaboration with partners from the business community, led to the successful introduction of new crops such as quinoa, tagetes and hemp into some areas of the Kingdom of the Netherlands.[14] Another project on diversification of cropping systems, DiverIMPACTS, aimed to improve productivity, the delivery of ecosystem services and the resource-use efficiency and sustainability of value chains in Europe.[15] Also in Europe, the projects ReMIX[16] and Diversifood[17] aimed, respectively, to develop diverse and resilient arable cropping systems through species mixtures and to increase diversity in crop production and food supply.

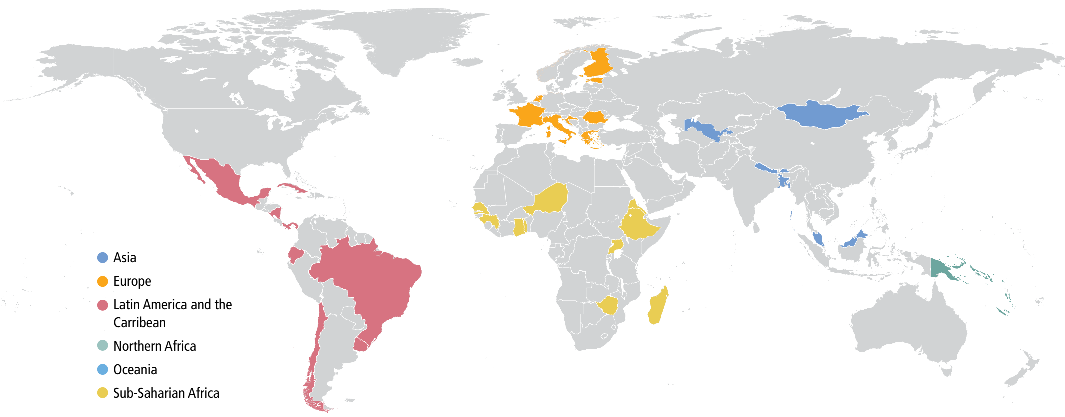
[14] Further information at https://www.wur.nl/en/research-results/research-institutes/plant-research/field-crops/better-products-new-crops.htm

[15] Further information at https://www.diverimpacts.net

[16] Further information at https://www.cropdiversification.eu/projects-involved/remix.html

[17] Further information at https://diversifood.eu/project

FIGURE 4.5
Countries reporting crops reintroduced from genebank collections



Notes: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Lin of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 30 country reports.

Instances of new introductions of pulses included pigeonpea in Jordan and Mali. Crop species belonging to the genera *Triticum* and *Sorghum* were the most frequently introduced cereals. Examples included the introduction of wheat into some sub-Saharan African countries. Pearl millet was introduced into Jordan and Kyrgyzstan. In Greece, more than 80 vegetable, pulse, fruit plant and herb and spice crops were introduced into 16 areas of the country. In Australia, 68 new introductions were made. Most crop groups were involved, the largest numbers of introductions being fruit plants (24), forages (15) and cereals (8).

The reintroduction of crops and crop diversity from genebanks was reported to be more prevalent in Latin America and the Caribbean (49 percent) and to a lesser extent in Europe (23 percent) and Asia (16 percent) than in other regions (Figure 4.5). In Cuba, for instance, 25 crops were reintroduced from genebanks. These included fruit plants (eight), forages and vegetables (six each). Other countries where many crops were reintroduced included Romania (19), Nicaragua (14) and Mexico (13).

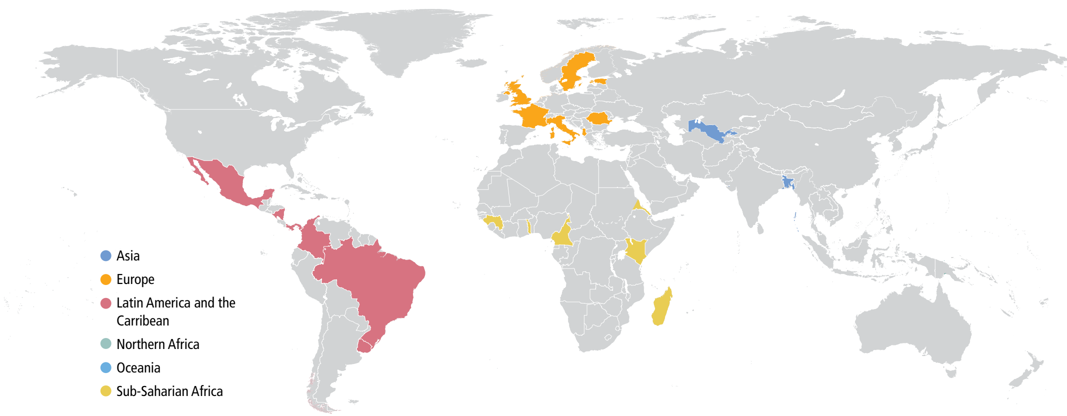
Figure 4.6 shows the distribution of countries that reported that wild species were introduced into cultivation during the reporting period. Introductions of wild species into cultivation were most common in Asia (52 percent). The crop groups with the largest numbers of wild species introduced were herbs and spices (20), fruit plants (18), medicinals (17) and vegetables (10). Lebanon introduced the highest number of wild species, the majority of which were herbs and spices and medicinal plants. Bangladesh introduced the second highest number, the majority of which were pulses.

4.8 Development and commercialization of farmers' varieties/landraces and underutilized species

In most parts of the world, high-input crop production is increasingly dominating agricultural systems. High-input systems, and the limited

FIGURE 4.6

Countries reporting on wild species introduced into cultivation



Notes: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Based on 18 country reports.

number of varieties of a few major crops grown within them, meet a large proportion of global demand. However, many species and farmers' varieties of both major and minor crops are being used by local communities to meet local demand for food, fibre, energy and medicine. Knowledge related to the use and management of these varieties and species is often localized and specialized. Increasingly, diversity at both species and variety levels is being replaced by uniformity in the agricultural marketplace. To support commercial production systems, varieties are bred to meet the strict needs of high-input production, industrial processing and demanding market standards.

Farmers' varieties and underutilized species are being marginalized by these trends and are thus being lost, along with the knowledge associated with them. Although there has been a modest increase in efforts to conserve such species *ex situ*, their overall diversity is not yet adequately represented in collections. Moreover, many underutilized crops are not included in Annex I of the International Treaty and thus cannot benefit from its MLS. Nonetheless, many of them have great potential for wider use and could contribute significantly to sustainable livelihoods through improved food security and nutrition, income generation and risk mitigation.

There is growing global recognition of the value of farmers' varieties and underutilized species in the face of uncertain climates, malnutrition and rural poverty. For example, there is evidence that both policymakers and the public are becoming increasingly aware of the importance of traditional vegetables and fruits and potential new energy crops. So-called niche or high-value markets are expanding, as consumers are increasingly willing to pay higher prices for better quality, novel foods from known sources. New legal mechanisms are enabling farmers to market "lost" heritage crops and farmers' varieties, and legislation supporting the marketing of geographically identified products has been put in place, providing incentives for farmers to conserve and use local crop genetic diversity.

4.8.1 Farmers' varieties/landraces

Twenty-nine countries[18] from five regions[19] report the registration and release of 523 FV/LR, 49 percent of which happened during the last two years of the reporting period, i.e. 2018 and 2019 (Table 4.8). These FV/LR were mostly fruit plants (231), roots and tubers (77), cereals (92) and vegetables (68). More than 95 percent of the registrations of FV/LR of fruit plants were in Europe. These were mainly apples and vines in Finland and France. In the case of roots and tubers, FV/LR of sweet potato and potato were released in Guyana and Peru, and of cassava, sweet potato, taro, coleus potato and yams in Ghana. Yams were also released in Nigeria and potatoes in Germany, France and Norway.

The highest figures for release and registration of cereal FV/LR were in Europe (45 percent). These were mainly in Germany (wheat, barley and maize) and in Finland (barley and rye). In second place, with about 38 percent of the releases and registrations, was sub-Saharan Africa, where the leading crops were rice in the Niger, maize in Ghana and sorghum in Mali and Nigeria. Finally, the largest number of FV/LR of vegetables were registered in Europe (75 percent). Two countries (Croatia and Germany) accounted for the majority, with registrations of *Brassica*, tomato, onion and garlic. Table 4.11 shows the number of registered and released varieties, and the crops and countries involved, for each year of the reporting periods.

Nearly 1 400 programmes on FV/LR and underutilized crops or species, variously pertaining to research, crop improvement, processing, public awareness, seed distribution, market development and policy changes, were implemented by 283 stakeholders in 75 countries during the reporting period. Among these programmes, 412 were specific to FV/LR, 159 targeted underutilized crops or species and 108 targeted both FV/LR and underutilized crops or species.

In Germany, old Bavarian landraces, including those on the German red list of endangered varieties, were characterized. Based on the data generated and those obtained through participatory variety assessment by stakeholders from the agricultural value chain, varieties with high potential for further cultivation were identified. A limited number of seeds resulting from these activities were then made available to interested farmers as well as to regional initiatives and institutions – referred to as "treasure keepers" – for trial cultivation. Selected varieties were then submitted for approval as conservation varieties, thereby ensuring their continued availability.

Supportive measures for the cultivation of local plant varieties, such as the Rural Development Plan in Estonia, helped promote the development, cultivation and commercialization of FV/LR and underutilized species. Seventy countries report the existence of national policies promoting the development and commercialization of FV/LR or underutilized species.

The successes reported by countries illustrate how much can be achieved through projects on the release and registration of FV/LR. Nonetheless, 14 countries report a lack of relevant laws and policies related to FV/LR.[20] In Czechia, no FV/LR were registered and commercialized during the reporting period.

4.8.2 Underutilized species with potential for commercialization

A total of 587 underutilized crop species with potential for commercialization were identified in 63 countries (Table 4.12). Fruit plants were the most represented crop group (29 percent), followed by vegetables (17 percent), and then roots and tubers, herbs and spices, medicinal plants, ornamentals, pulses and cereals (6 percent

[18] Armenia, Azerbaijan, Bangladesh, Bhutan, Costa Rica, Croatia, Estonia, Ethiopia, Finland, France, Germany, Ghana, Guatemala, Guyana, Jordan, Latvia, Malawi, Mali, Nepal, Niger, Nigeria, Norway, Panama, Peru, Philippines, Portugal, Serbia, Sri Lanka, Sudan.

[19] Asia, Europe, Latin America and the Caribbean, Northern Africa, sub-Saharan Africa.

[20] Australia, Belarus, El Salvador, Ghana, Guatemala, Nigeria, Papua New Guinea, Philippines, Republic of Moldova, Senegal, South Africa, Trinidad and Tobago, Tunisia, Zimbabwe.

TABLE 4.11
Number of farmers' varieties/landraces of different crops released and registered over the period 2012 to 2019

Year	Crops	Number of FV/LR	Country
2012	Barley, cauliflower, cabbage, garlic, horseradish, frafra potato, pearl millet, potato, plum, sorghum, maize, rice, rye, tomato	33	Azerbaijan, Bhutan, Croatia, Germany, Ghana, Niger, Norway, Sudan, Serbia
2013	Amaranth, bread wheat, cabbage, chickpea, canistel, common bean, maize, muskmelon, onion, parsley, pepper, oat, parsnip, radish, rice, rye, spelt wheat, sugar beet, tomato	45	Armenia, Croatia, Germany, Malawi, Panama, Portugal, Sri Lanka, Sudan
2014	Common bean, cucumber, garlic, flax, maize, mustard, pear, pumpkin, oat, tomato, watermelon, white mustard	17	Germany, Croatia, Philippines, Serbia
2015	Bread wheat, buckwheat, cassava, cebada, cowpea, cocoyam, lettuce, onion, malanga, maize, pearl millet, pepper, potato, sorghum, tef	51	Croatia, Ghana, Ethiopia, Finland, Germany, Mali, Peru
2016	Barley, bread wheat, cowpea, rice, rye	9	Costa Rica, Finland, Germany, Ghana
2017	Barley, blackcurrant, bread wheat, common bean, garlic, longan, mango, Manila hemp, pea, pear, plum, red clover, red currant, red raspberry, sour cherry, spelt wheat, white currant, yam	35	Finland, Germany, Ghana, Philippines, Portugal
2018	Apple, barley, bread wheat, common bean, cucumber, hemp, lettuce, mango, pear, plum, potato, sorghum, sour cherry, sweet cherry	145	Colombia, Finland, Germany, Mali, Nigeria, Peru, Philippines
2019	Apple, blackcurrant, bread wheat, cassava, castor, frafra potato, gooseberry, hemp, mango, mustard, pea, pear, potato, red currant, red raspberry, rye, sour cherry, sweet potato, white currant, yam	235	Colombia, Finland, Ghana, Germany, Nigeria, Philippines

Note: FV/LR = farmers' varieties/landraces.

each). In all, 127 of the underutilized crops were reported to be of high priority for further research and commercialization in at least one country. The six crop groups most represented among these were vegetables (24 percent), fruit plants (15 percent), herbs and spices (10 percent), roots and tubers (9 percent), pulses (8 percent) and pseudo-cereals (6 percent). Sixty-six (52 percent) of the high priority underutilized crop species were reported from Asia, with significant numbers of vegetables (e.g. eggplants, cucurbits and okra) and pulses (e.g. lentils in Bangladesh and Jordan, and broad bean in India) among them. Thirty-one percent of the high priority crop species were reported from Latin America and the Caribbean. About 15 of these species were roots and tubers, which included yam and cocoyam in Cuba and El Salvador, and cassava in Costa Rica, Cuba and Guyana.

In 53 countries, the underutilized species identified as having potential for commercialization were assigned to categories ranging from high to low potential for further development and commercialization. Figure 4.7 shows the number of species assigned to each of these categories. Figures 4.8 to 4.11 show the number of the underutilized species with potential for commercialization for which different degrees of progress have been achieved in crop improvement (based on responses from 53 countries), marketing (49 countries), multiplication of seeds and planting materials (53 countries), and geographical distribution mapping (54 countries).

Twenty-three countries report some level of crop improvement activity for (in total) about two-thirds of the 182 underutilized crop species with high or medium-high priority (Table 4.13). Varying levels of characterization and/or evaluation and seed multiplication activities were reported for these crops. The countries with the most high or medium-high priority underutilized crops were Bangladesh (35 species, including Indian spinach and several cucurbits and

TABLE 4.12
Number of underutilized crop species with potential for commercialization, by crop group and region

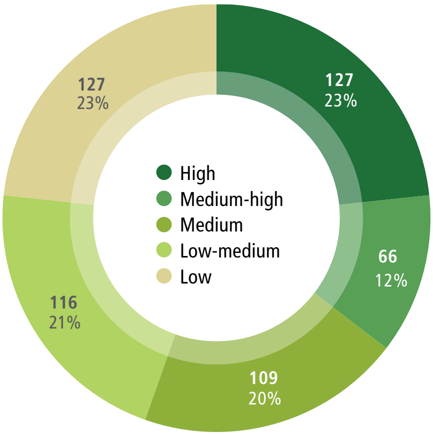
Crop group	Number of underutilized crops						
	Northern Africa (3 countries)	Sub-Saharan Africa (18 countries)	Latin America and the Caribbean (12 countries)	Oceania (1 country)	Asia (16 countries)	Europe (13 countries)	Total (63 countries)
Fruit plants	1	20	132	2	18	13	172
Vegetables	5	19	38	1	44	29	100
Roots and tubers		13	28	1	1	1	37
Herbs and spices	1	1	7		17	12	35
Medicinal plants		5	10	1	10	12	35
Ornamentals		4	27		1	3	35
Pulses	1	5	12		20	15	34
Cereals	10	7	2	1	14	8	33
Forages	15		10	1	4	3	32
Oil plants	1	4	4		11	4	15
Pseudo-cereals		3	4		4	4	12
Material plants		3	6		2	1	12
Nuts		3	5		3	3	11
Stimulants			9	1			9
Fibre plants			5		1	2	7
Other	1		5		1	1	8
Total	35	87	304	8	151	111	587

brassicas), El Salvador (19, including dragon fruit, arrowroot and pigeonpea), Mexico (18, including annonas and several cacti), Albania and Lebanon (17 each, including several herbs and spices in both countries), Cuba (16, including roots and tubers such as sweet potato, yam and cassava), Uganda (12, including amaranth and mango)and the Islamic Republic of Iran (10, including millets and oil plants such as camelina, rapeseed, safflower, soybean and sunflower).

Colocasia esculenta (taro) is the underutilized crop species with potential for commercialization that was reported by the largest number of countries, namely Cuba, Ghana, El Salvador, Indonesia, Malaysia, Mexico and Uganda. In Cuba and El Salvador, it was assigned a high priority. Finger millet and pearl millet were reported by six countries each, the former with medium-high priority in Ethiopia, Nepal and Zambia and lower priorities in Bhutan, and Zimbabwe, and the latter with high priority in the Islamic Republic of Iran, medium priority in the Sudan and Togo and lower priorities in, Bangladesh, Tunisia and Zimbabwe. Amaranth, roselle, sorghum, lentil, common bean and sweet potato are among the other crops reported by large numbers of countries as having potential for commercialization.

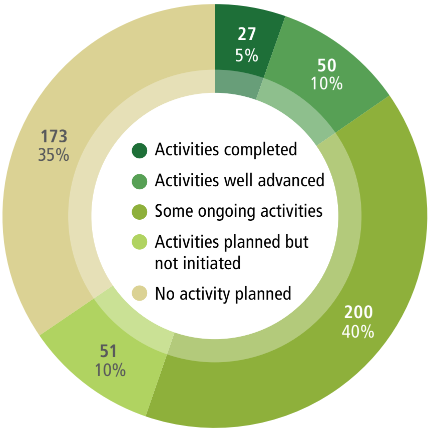
Box 4.2 presents two initiatives reported by countries on the development and commercialization of FV/LR and underutilized species.

FIGURE 4.7
Number and proportion of underutilized species assigned to different priority levels with respect to their potential for commercialization



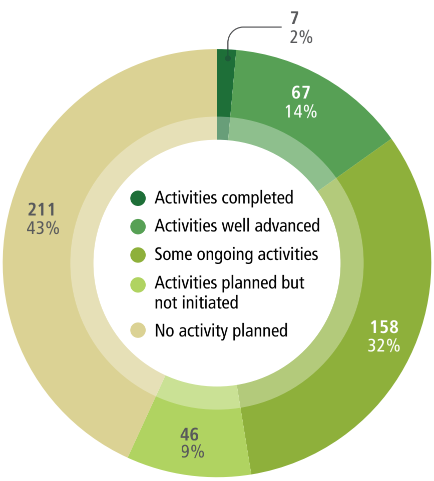
Note: Based on 53 country reports.

FIGURE 4.8
Summary of the status of crop improvement activities in underutilized species identified as having potential for commercialization



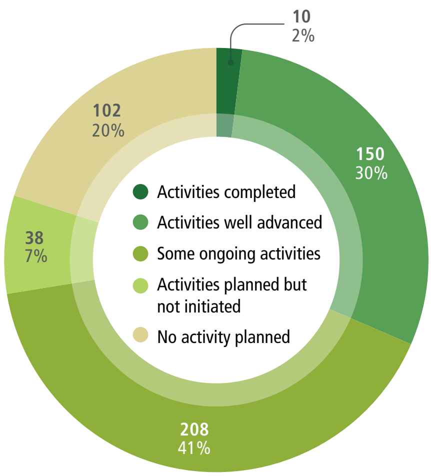
Notes: Pie chart shows number and percentage of species in each category. Based on 53 country reports.

FIGURE 4.9
Summary of the status of marketing activities for underutilized species identified as having potential for commercialization



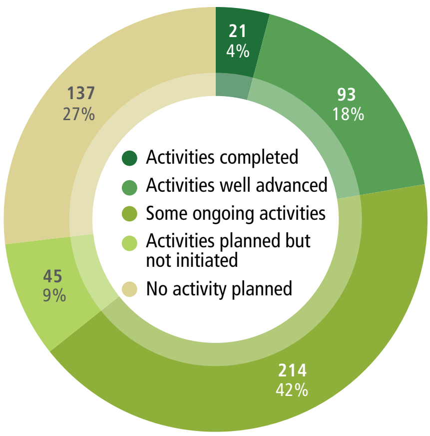
Notes: Pie chart shows number and percentage of species in each category. Based on 49 country reports.

FIGURE 4.10
Summary of the status of multiplication of seed/ planting materials in underutilized species identified as having potential for commercialization



Notes: Pie chart shows number and percentage of species in each category. Based on 53 country reports.

FIGURE 4.11
Summary of the status of mapping the geographical distributions of underutilized species identified as having potential for commercialization



Notes: Pie chart shows number and percentage of species in each category. Based on 54 country reports.

4.9 Strengthening seed delivery and distribution systems

Effective seed delivery and distribution systems that ensure that farmers have timely access to sufficient quantities of quality seeds and planting materials are crucial if the full benefits of diversification are to be realized. The formal and informal seed systems co-exist in nearly all countries. The informal system involves the exchange of traditional varieties and landraces among farmers. NGOs that work in close collaboration with smallholders to produce and distribute seeds also operate within the informal system. The formal system involves government-regulated production and distribution of quality-assured seeds, typically with the involvement of private-sector seed companies and nurseries that may produce seeds and seedlings locally or import and multiply them.

There was considerable growth in the seed systems of many countries between 2012 and 2019, and this facilitated the adoption of suitable varieties by farmers. The value of the global seed market has undergone unprecedented growth in recent years, increasing from USD 36 billion in 2007 to over USD 50 billion in 2020. The United States ranked first in terms of the share of the global seed market as of 2020, followed by China, France, Brazil and Canada. Countries whose national seed sectors showed the most growth in recent years include China and Türkiye. In China, a total of 6 393 seed companies were registered in 2020 as compared to 730 in 2018. Türkiye produced a total of 1.32 million tonnes of certified seed in 2021, doubling the amount produced in 2011. The seed market in the Asia–Pacific region grew at a phenomenal rate in 2021 and had a market value of USD 22.91 billion (APSA, 2022).

Adherence to the seed-testing guidelines established by the International Seed Testing Association improved the overall quality of seeds. For example, in Egypt, the Central Administration for Seed Production administered the quality assurance and production of foundation seeds and other seed classes in the country, ensuring that quality seeds were continuously available to farmers.

The Organisation for Economic Co-operation and Development (OECD) Seed Schemes engaged with the national designated authorities of its 61 member countries to ensure adherence to certification standards and procedures and thereby facilitated the movement of quality seed across borders. The total volume of seeds certified by the OECD Seed Schemes doubled during the reporting period. A total of 69 643 plant varieties, belonging to 204 species, were registered in the 2019–2020 period, with maize varieties accounting for the largest number of them (49 percent), followed by other cereals, crucifers, and oil or fibre species. The OECD certified 1 035 million kg of seeds in 2019–2020, with an estimated value of USD 1.6 billion. In the 2019–2020 period, the Islamic Republic of Iran, France, Italy and the United States were

TABLE 4.13
Number of underutilized crops with high or medium-high priority with respect to their potential for commercialization, by crop group and region

Crop group	Number of underutilized crop species				
	Sub-Saharan Africa (9 countries)	Latin America and the Caribbean (8 countries)	Asia (10 countries)	Europe (3 countries)	Total (30 countries)
Vegetables	8	6	23	8	40
Fruit plants	3	18	6	4	30
Roots and tubers	2	17			18
Pulses	3	3	12	3	17
Herbs and spices	1	2	9	4	16
Cereals	6	2	9		12
Ornamentals		9	1		10
Pseudo-cereals	3	3	3	1	9
Medicinal plants	2	2	3	1	8
Oil plants	1		7		8
Forages		4	1		5
Nuts		1	3		4
Stimulants		2			2
Material plants		1			1
Other		1	1		2
Total	29	71	78	21	182

Box 4.2
Development and commercialization of farmers' varieties/landraces and underutilized species

In Uganda, renewed interest in the development and commercialization of products from previously neglected and underutilized species has yielded dividends. There is a growing desire among the country's emerging middle class for healthier diets and healthier food products. Neglected and underutilized species targeted for product development and commercialization to meet this demand have included *Tamarindus indica, Telfairia occidentalis, Mondia whitei, Psorospermum species, Persea americana, Abelmoschus esculentus, Artocarpus heterophyllus, Hibiscus rosa-sinensis, Zingiber officinale, Cucurbita species, Cymbopogon citratus, Serenoa repens* and *Dioscorea* species.

The Heritage Seeds Project was initiated in October 2015 in the Kingdom of the Netherlands by the Oerakker Foundation,[a] supported by the Centre for Genetic Resources, with the aim of producing the seeds of heritage varieties (including varieties of old bitter Brussels sprouts, tomato, pea, bean and wheat). The aim was to safeguard traditional Dutch agricultural and horticultural crops and varieties. Another body, the Zaadgoed Foundation,[b] supports farmer and community-based plant breeding and the conservation of traditional varieties for organic agriculture.

[a] Further information at https://www.seeds4all.eu/seed-operators/netherlands/de-oerakker
[b] Further information at https://zaadgoed.nl/english

the largest producers of OECD-certified seeds, collectively contributing 74 million kg of seeds.[21]

SADC's Harmonized Seed Regulatory System aims to facilitate access to quality seeds in the subregion, in particular via cross-border trade. The functioning of the SADC Seed Security Network, which aims to improve the food security of smallholders through increased availability of, and access to, quality seeds, was strengthened in 2015–2016 by the US Government-funded Feed the Future Southern Africa Seed Trade Project. This initiative contributed, for instance, to the production and export of nearly 200 tonnes of maize seeds by Seed Co Zambia Limited to the Democratic Republic of the Congo. The success motivated other seed companies (e.g. Lake Agriculture in Zambia, Zimbabwe Super Seeds cooperative in Zimbabwe, and Peacock Seeds in Malawi) to join the Seed Trade Project to produce and export quality maize and bean seeds to Mozambique. In all, these four seed companies produced 700 tonnes of quality seeds, which were exported to the Democratic Republic of the Congo and Mozambique, or were sold domestically in the respective producing countries.

The CGIAR Research Programme on Grain Legumes and Dryland Cereals facilitated the establishment of viable seed systems in sub-Saharan Africa and Asia, leading to a greater adoption of improved crop varieties. As discussed by Ojiewo *et al*. (2020), a total of 397 050 tonnes of certified and quality-declared seeds of three legume crops were produced across three countries – the United Republic of Tanzania (groundnut), Nigeria (cowpea) and Uganda (common beans) – under the Tropical Legumes Projects funded by the Bill & Melinda Gates Foundation.[22] Both crop area and productivity increased following the planting of the quality seeds in the target countries over the project period (2007 to 2019). For instance, the harvested area of groundnut increased from 40 000 hectares to 1.6 million hectares and yields increased from 0.6 tonnes to 1.2 tonnes per hectare in the United Republic of Tanzania. Cowpea yields rose from less than 0.5 tonnes to 1.1 tonnes per hectare in Nigeria. The Tropical Legumes Projects were led by ICRISAT in collaboration with CIAT, IITA and national agricultural research systems (NARS) partners in Africa and India.

Similarly, the MyPulses project (2014 to 2017), which was funded by the Australian Centre for International Agricultural Research and involved ICRISAT and Myanmar's Department of Agriculture Research and Department of Agriculture, contributed to the remarkable improvement made in chickpea production in Myanmar in recent decades (an increase in the area under chickpea cultivation from 101 172 hectares to 368 390 hectares and in the yield per hectare from 668 kg to 1 384 kg between 1998 and 2018) (Ojiewo *et al*., 2020). The initiative Village Seed Bank Program provided quality seeds of improved cultivars directly from the Department of Agriculture and achieved an unprecedented rise in chickpea seed quality (Ojiewo *et al*., 2020).

Notable among similar initiatives aimed at developing economically sustainable seed systems for smallholder farmers in developing countries was Building an Economically Sustainable and Integrated Cassava Seed System, Phase 2 (BASICS-II),[23] which was led by IITA, funded by the Bill & Melinda Gates Foundation and involved Go Seed,[24] the Tanzania Official Seed Certification Institute, the National Root Crops Research Institute, Nigeria, and the Mennonite Economic Development Agency as collaborating partners. The project resulted in increased production of early-generation cassava seed via strengthened public–private partnerships and linkages between seed entrepreneurs and processors. The BASICS-II project led to the establishment of seamless links with other schemes in sub-Saharan Africa, such as Building an Economically Sustainable Seed System for Cassava in the United Republic of Tanzania,[25] to increase the availability of quality

[21] Further information at https://www.oecd.org/agriculture/seeds.
[22] Now known as the Gates Foundation.
[23] Further information at https://cassavamatters.org/basics-ii
[24] Further information at https://iitabip.com/goseed
[25] Further information at https://www.meda.org/projects/best-cassava

seeds of improved and disease-resistant varieties to farmers and seed entrepreneurs.

The increasing number of crop varieties that were released and registered during the reporting period complemented the considerable improvement in the seed production capacity of various countries. In the United Republic of Tanzania, capacity to produce quality seeds increased by 110 percent between 2015/16 and 2019/20, resulting in a 53 percent reduction in seed imports. Similarly, in Nigeria, the production of certified seeds increased from 14 788 tonnes in 2011 to 170 692 tonnes in 2014, and the number of accredited seed entrepreneurs rose from 71 in 2012 to 314 in 2018. Also in Nigeria, an initiative known as the Growth Enhancement Support scheme was introduced to deliver government-subsidized farm inputs, including certified seeds, directly to farmers. Some countries, for example Botswana, report that the level of adoption of released varieties during the reporting period was not easily quantifiable, as farmers could exchange seeds between themselves without keeping records. The number of registered seed enterprises in Botswana, however, increased from two in 2014 to 517 in 2019. The regular inspection of these enterprises contributed to seed quality assurance.

The greater availability of quality seeds of new (less than ten-year-old) high-yielding varieties of pulse crops to smallholder farmers in India led to a significant increase in pulse production from 14.76 million tonnes in 2007 and 2008 to 24.42 million tonnes in 2020 and 2021. The project "Creation of seed hubs for increasing indigenous production of pulses in India",[26] which was initiated in 2016 by the Government of India's Ministry of Agriculture & Farmers Welfare and implemented through the Indian Council of Agriculture Research (ICAR) – Indian Institute of Pulses, contributed to this achievement.[27] The production targets for different pulse crops (chickpea, pigeonpea, lentil, pea, mungbean, urdbean, lathyrus, horsegram, mothbean, common bean and cowpea) were achieved through 150 seed hubs located in 24 states; these hubs engaged 46 All India Coordinated Research Project Centres in different state/central agricultural universities, seven ICAR institutes and 97 Krishi Vigyan Kendras (agriculture science centres) (Rubyogo *et al*., 2019). The ICAR Agricultural Technology Application Research Institutes played an important role in facilitating farmer access to quality seeds under the auspices of the project.

[26] Further information at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1716492

[27] Further information at https://iipr.icar.gov.in/iiprseedportal

4.10 Changes since *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*

Since the end of the reporting cycle for the SoW2 (FAO, 2010), crop improvement programmes have accorded high priority to breeding for adaptation to the effects of climate change and to reducing the negative impacts of crop production systems on the climate. Moreover, there was greater awareness of the importance of underutilized species in diversifying smallholder production systems, as well as improved understanding that efforts to achieve food security and nutrition targets are constrained by overreliance on a limited number of food crops. The constraints to the use of PGRFA described in the SoW2 (and in the SoW1), including inadequate human resources, funding and facilities, were still evident in this reporting cycle.

There were some advances in the characterization and evaluation of the germplasm of species of outstanding economic importance in national collections and – more especially – in major national genebanks. Tremendous advances occurred in the field of high-throughput genotyping, phenotyping and modern breeding techniques, such as genomic selection. Projects involving collaboration between international organizations such as CGIAR and NARS partners were crucial in the development and exchange of genetic resources and technologies.

The routine use of novel techniques to address identified problems requires specialized skill sets. The training of a new generation of plant breeders in developing countries in the use of modern biotechnologies is therefore of paramount importance. Establishing and supporting training centres, such as the West Africa Centre for Crop Improvement,[28] and promoting collaborative programmes involving them, would help achieve this.

A growing realization of the vulnerability of cropping systems to abiotic and biotic stresses, including those that result from climate change, has fuelled renewed interest in diversifying crop production. Considerable progress was made in the production of high-quality seeds and making them available to farmers at affordable prices. For instance, the seed hubs established by ICAR were instrumental to the record pulse harvests obtained in India in recent years.

4.11 Gaps and needs

Policy support

National seed policies and regulations supporting the co-existence of diverse seed systems are lacking in many countries. For example, there is a lack of policies specifically dedicated to promoting the commercialization of FV/LR and underutilized species, undermining efforts to increase on-farm diversity and diversify diets. The development of national policies and programmes for these categories of crops is therefore needed, with particular emphasis given to their identification for large-scale cultivation, marketing and consumption. There is also a need to develop and implement national seed policies and regulations that facilitate the participation of a multiplicity of stakeholders along the value chain and enable the co-existence, where necessary, of diverse seed systems. Seed quality assurance mechanisms need to be strengthened, preferably based on internationally agreed standards and guidelines, in order both to enhance the availability of quality seeds and to prevent the sale of counterfeit, non-quality assured seeds and planting materials.

Some countries lack national strategies for plant breeding, and this limits the implementation of solution-oriented crop improvement programmes. Plant breeding is also constrained by the continued disappearance of local varieties because of declining farmer populations and by the erosion of CWR in the wild, which limit access to valuable sources of traits for breeding superior crop varieties. Coordination and collaboration are needed among ministries of agriculture and environment, and their research institutions, to ensure that plant breeding is added to national plans and to strengthen *in situ* conservation and on-farm management of PGRFA at the national level.

To capture the potential market value of farmers' varieties and underutilized species, there is a need to better integrate the efforts of stakeholders from different parts of the production chain. In particular, the involvement of local communities is essential, as is fully accounting for traditional knowledge systems and practices.

To promote the cultivation and commercialization of farmers' varieties and underutilized species, stronger demand and more reliable markets for these materials and their products are needed. There is also a need to promote local processing, commercialization and distribution of the products of farmers' varieties and underutilized species. Finally, increased public awareness of the value of farmers' varieties and underutilized species is needed to enlarge the consumer community for such products.

Funding mechanisms

Some countries report a lack of funding for their national programmes on the molecular characterization of PGRFA. The number of funded PGRFA projects at national level decreased during the reporting period.

[28] Further information at https://wacci.ug.edu.gh

The limited involvement of the private sector in pre-breeding and germplasm enhancement may be constraining the injection of funding for validated innovative technologies that can harness the potentials of PGRFA. The implementation of long-term investment and research plans on pre-breeding to improve the utilization of PGRFA, particularly CWR, landraces and underutilized species, is therefore crucial.

Application of modern biotechnologies

The level of application of modern biotechnologies and molecular genetic tools in developing countries is low overall. Modern biotechnologies and molecular genetic tools remained too costly for routine use in crop breeding programmes in these countries during the reporting period. There is a need to strengthen institutional and human capacities to use novel, efficiency-enhancing technologies, especially in emerging areas such as gene editing, genomic selection and high-throughput phenotyping.

Data and information sharing

There is a general lack of linkages between accessions (the physical germplasm) and data and information related to them (e.g. phenotyping data and molecular data). A lack of characterization and evaluation data meant that targeted selection of accessions possessing specific traits or characters remained challenging during the reporting period, especially for genebank managers. Most existing characterization and evaluation data were not publicly available. The lack of standardization in the collection and curation of phenotypic data from different sources impeded the comparison and analysis of datasets. Standardization of data generated from the recently emerged "omics" disciplines was also problematic. The need for standardization of characterization and evaluation of germplasm to ensure better interoperability of databases and easier exchange of information is clear. There is also a need to establish linkages between accessions and the various types of data generated by genebanks and their clients.

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Chapter 5

THE STATE OF HUMAN AND INSTITUTIONAL CAPACITIES

Chapter 5

The state of human and institutional capacities

5.1 Introduction

The conservation and sustainable use of PGRFA entail more than the immediate management of germplasm. They depend on a range of fields of activity, including policy, legislation, infrastructure, education and networking. Capacities in these fields constitute the subject matter of this chapter.

Since the publication of SoW2, a number of global changes have significantly shaped the context for the management of PGRFA. Chief among these is the increase in frequency of disruptive and catastrophic weather events, an indication of the palpable impact that climate change is having. Addressing climate change has moved to the forefront of the international agenda, which since 2015 has been framed by the SDGs. Similarly, the period since the publication of the SoW2 has also been characterized by concerns about the loss of biodiversity and declines in soil health, and greater recognition of the need for agroecological transformation of food and farming systems. Against this background, awareness of the importance of PGRFA has grown, especially in terms of their crucial role in food security and nutrition, the livelihoods of smallholder farmers, and the sustainability of agriculture in the face of climatic uncertainty and biodiversity loss. This awareness has encouraged greater attention to, and investments in, the conservation of these resources.

The international governance framework for genetic resources has also seen noteworthy development, specifically with the entry into force in 2014 of the Nagoya Protocol, the adoption in 2021 by FAO of the Framework for Action on Biodiversity for Food and Agriculture, and the Global Plan of Action for the Conservation, Sustainable Use and Development of Aquatic Genetic Resources for Food and Agriculture, and the adoption of the Kunming-Montreal Global Biodiversity Framework in December 2022. These international agreements are intended to be implemented in a mutually supportive manner and will support the implementation of the GPA2 and the International Treaty. However, implementing them in a harmonious way also places greater demands on human and institutional capacities.

The developing governance framework for PGRFA has increasingly emphasized the rights of smallholder and peasant farmers, Indigenous Peoples and local communities, as applicable, and specifically women and youth, and their participation in decision-making. While this has been a focus since before adoption of the first GPA, it has acquired renewed emphasis over the last decade, as farmers, Indigenous Peoples and local communities, have gradually been better integrated into international negotiations. Examples include such mechanisms as the Permanent Forum on Indigenous Issues under the UN's Economic and Social Council, established in 2000,[1] the Civil Society and Indigenous Peoples' Mechanism for relations with the UN Committee on World Food Security, established in 2010[2], and the UN Declaration on the Rights of Peasants

[1] Further information at https://www.un.org/development/desa/indigenouspeoples/about-us/permanent-forum-on-indigenous-issues.html

[2] Further information at https://www.csm4cfs.org/

and Other People Working in Rural Areas (UN General Assembly, 2018).

Crucially, digital technologies and biotechnologies have seen remarkable new developments. New molecular techniques have led to a drastic reduction in the costs and time involved in generating DNA and RNA sequence data. These developments are increasing the efficiency of the characterization of PGRFA and speeding up the development of new crop varieties through such techniques as marker-assisted selection, genomics-assisted breeding and gene editing. However, the technical capacity to generate and manage this information and utilize these technologies is unevenly distributed across regions and institutions, mirroring wider economic and geopolitical asymmetries, and this uneven distribution of capacity constrains equitable access to the benefits arising from PGRFA use. Advances in these fields have also led to discussions and, recently, a decision at the international level with regard to the distribution of benefits arising from the use of DSI. The decision adopted by the Conference of the Parties to the Convention on Biological Diversity in 2024 (CBD, 2024) operationalizes a multilateral mechanism for the fair and equitable sharing of benefits from the use of DSI on genetic resources.

Social media and other online communication tools have greatly transformed the ways in which the wider public, as well as professional communities, share information. This has also had an impact on the delivery of education, including in the context of PGRFA, often facilitating participation and increasing training opportunities. However, the amount of information available online today can be overwhelming and requires improved skills to assess and evaluate its credibility and reliability. Likewise, continuous capacity building to keep pace with technological and informational developments is needed.

This chapter is based on a literature review and an analysis of country reports submitted in the context of reporting requirements for monitoring the implementation of the GPA2. Country reports were mined for key information pertaining to Priority Activities 13 to 18 of the GPA2.[3] Sections 5.2 to 5.6 document achievements and remaining gaps and needs in these priority areas. The country reports were also used to analyse differences among regions for each priority activity.

The analysis is based on countries' own assessments. Moreover, each component of the analysis only covers the countries that reported on their actions and needs in the respective priority area. As not all countries responded to all questions, the total numbers of respondents vary, and this hinders precise comparisons. The chapter also draws on information available from the International Treaty on ongoing work under its ambit. Given that approximately two decades have passed since the International Treaty came into force in 2004, the chapter highlights the critical role that this instrument has played to date, outlining some key developments and reviewing some of the major achievements and lacunae in its implementation.

5.2 Overview of human and institutional capacities

Globally, human and institutional capacities to use and conserve PGRFA have increased since the publication of the SOW2, although progress has been uneven across key areas of PGRFA conservation and sustainable use, and across regions and countries. In general, these advances appear inadequate to fully implement the GPA2. Strengthening human and institutional capacities remains essential for the

[3] Priority Activities (PAs) 13 to 18 are covered in this chapter: PA 13 Building and strengthening national programmes; PA 14 Promoting and strengthening networks for PGRFA; PA 15 Constructing and strengthening comprehensive information systems for PGRFA; PA 16 Developing and strengthening systems for monitoring and safeguarding genetic diversity and minimizing genetic erosion of PGRFA; PA 17 Building and strengthening human resource capacity; PA 18 Promoting and strengthening public awareness of the importance of PGRFA.

implementation of the GPA2 and for meeting other related commitments, such as the SDGs and relevant targets of the Kunming-Montreal Global Biodiversity Framework.

During the reporting period, incremental progress has been made in establishing and strengthening national programmes, as well as developing strategies to guide their operations. The development of NBSAPs has been identified as a catalysing factor in this regard. However, fewer than half the countries (37 countries) reported progress in the development of PGRFA-specific strategies or relevant legislation. Collaboration among national stakeholders and institutions remains weak, while initiatives that are driven by civil society organizations are usually insufficiently supported and not well integrated into national programmes.

Education and training opportunities, particularly at the secondary school level, increased slightly during the reporting period. However, although approximately 80 percent of reporting countries had postgraduate level educational programmes, 27 percent (six countries) in sub-Saharan Africa did not. Additionally, the only reporting country from Melanesia, despite being very rich in plant diversity, reported neither undergraduate nor postgraduate education programmes on PGRFA. Yet, a significant increase was observed in the number of personnel working in key institutions with higher levels of educational qualifications, typically at the master's and doctoral levels.

In addition to educational institutions, other stakeholders, such as botanical gardens, genebanks, seed networks, research institutes, regional and international organizations, NGOs, foundations, associations and museums, contributed to training and capacity development. Cooperation among universities, networks, research institutes, and regional and international genebanks also increased, leading to joint educational and research activities in 43 percent of reporting countries. The increased use of online tools and platforms, coupled with the development of several innovative teaching materials – including videos and e-learning resources – enhanced participation in training programmes from remote locations.

Despite progress made during the reporting period, there is a need to strengthen academic institutions and develop educational programmes on plant breeding, genetic improvement and biotechnology in all regions. Similarly, there is a need for more targeted training courses, in all technical and legal aspects of PGRFA, aimed at a greater number of professionals, farmers and civil society.

A younger generation of professionals is needed to replace retiring experts in many countries, with efforts to build sufficient capacity and transfer knowledge. The chronic lack of research funding, including for scholarships, post-doctoral fellowships and long-term breeding programmes, remains a major bottleneck to strengthening capacities in the management of PGRFA. Weaknesses in collaboration and partnerships within and between national higher education institutions, research centres, networks and international institutions also remain unaddressed in many countries.

More than 90 percent of the reporting countries are members of networks for the management of PGRFA. These networks remain important hubs of activity for promoting the conservation and sustainable use of PGRFA, and the important benefits of international collaboration are widely recognized among stakeholders. For example, many publications have been produced through participation in these networks.

While some new networks have been initiated and others have renewed their efforts, other important regional networks, such as the Caribbean Plant Genetic Resources Network (CAPGERNET), the Cooperative Program on Research and Technology Transfer for the South American Tropics (PROCITROPICOS) and the Mesoamerican Network of Plant Genetic Resources (REMERFI) in Latin America and the Caribbean, have had to pause or cease their activities. Many networks are managed by volunteers and depend on short-term project funds, leading to fragility.

In addition, coordination and collaboration among different stakeholders within and among networks at the regional and international levels is often suboptimal.

International information systems have expanded and proliferated. Cross-platform interoperability and data-sharing initiatives have been further advanced with the development of the International Treaty's Global Information System (GLIS), including Genesys and WIEWS. The application of DOIs under GLIS has continued to provide opportunities to improve efficiencies in tracing germplasm through research publications. The UN General Assembly's adoption in 2017 of SDG Indicator 2.5.1.a on *ex situ* conservation stressed the key role of genebanks in preserving PGRFA and fostered country reporting and dissemination of standardized information through WIEWS.

As of 2019, almost 56 percent of 59 countries reporting on this topic had an operational genebank management information system for PGRFA in place. The recent development of GRIN-Global Community Edition has expanded the opportunities for genebanks to adopt an open-access and user-friendly genebank information management system; 12 countries reported that they are considering its adoption. Although it is increasingly addressed, there remains scope to improve the interoperability of existing information systems through the adoption of shared and open standards.

Despite numerous advances, a significant amount of data, particularly from characterization and evaluation trials, are not readily available or publicly accessible. Data standardization remains a major challenge, although the progressive adoption of DOIs and advancements in Artificial Intelligence promises improvements in this area. This situation was even more challenging with regard to data on the geographic distribution of CWR and FV/LR, for which systematic monitoring and inventory remains an unattained objective in all countries. Additionally, traditional knowledge on PGRFA appears to be rarely documented, nor included in information systems where documentation exists.

There is also often a lack of technological capacity to both manage and access information on PGRFA. Overall, key constraints to strengthening information systems are weaknesses in expertise on plant taxonomy, information management and bioinformatics; a lack of necessary digital infrastructure; and suboptimal funding and financial support.

During the reporting period, only a few countries had a national system for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Many countries reported continued concern over the extent of genetic vulnerability and the need for a greater deployment of diversity in cropping systems. Awareness increased on the importance of establishing mechanisms for monitoring genetic erosion, especially as part of *in situ* conservation approaches.

There remains a critical need to develop mechanisms for monitoring genetic erosion, especially for PGRFA conserved *in situ*, in most national and regional contexts. Surveys and baseline studies are needed, as well as indicators to assess genetic vulnerability and erosion. The lack of dedicated budgetary resources or long-term funding, as well as weak coordination among stakeholders, remain significant hurdles to overcome to assess and effectively address genetic erosion.

The number of accessions included under the International Treaty's Multilateral System (MLS) increased from approximately 600 000 in 2014 to more than 2.3 million in 2022, indicating the progress made in making PGRFA available for research, breeding and training activities under the MLS. Some national and regional genebanks apply the same terms and conditions of the SMTA for Annex I crops also for the provision of PGRFA that do not fall under the MLS.[4]

Farmers' Rights, as provided for in Article 9 of the International Treaty, remained topical during the reporting period, as indicated by the development

[4] Not listed in the International Treaty's Annex 1.

of an inventory of national measures, best practices and lessons learned from the realization of Farmers' Rights, under the coordination of the Ad Hoc Technical Expert Group on Farmers' Rights of the International Treaty.

There was an increase in the routine participation of farmers, Indigenous Peoples and local communities, and the wider public in decision making and the co-development of solutions related to PGRFA. International institutions, countries and national stakeholders increasingly instituted mechanisms to foster this pluralism. However, there remains significant scope for increasing participation of these groups in decision making related to the management of PGRFA, especially by strengthening capacities for facilitating participatory processes.

Almost 80 percent of the 89 countries reporting on this topic had a public awareness programme in place. No formal programme existed in Northern America, while in the other regions the percentage of countries with a programme varied between 63 percent in Latin America and the Caribbean to 90 percent in sub-Saharan Africa. The increasing number of awareness-raising activities corresponds with an increase in public understanding on the complexities of the management of PGRFA. It appears that decision makers, civil society and farming communities have become more aware of the importance of PGRFA and its associated challenges. Greater attention is given to the importance of conserving local crop diversity by promoting the diversity of native varieties, as well as local seeds and traditional food products and their nutritional value. New actors with strong linkages to farmers and rural communities – such as civil society organizations, social movements and seed networks – increasingly participate in the dissemination of information. Additionally, the increased use of digital and social media platforms has expanded the reach of information dissemination on PGRFA to a much broader audience, including young people.

National communication strategies and targeted public awareness programmes on the value of PGRFA require continued renewal and dedicated resources. Although many countries have an overall public awareness programme, interinstitutional coordination, collaboration and partnerships on communication activities – including engagements with media organizations – remain weak across all regions, resulting in shortcomings in information dissemination. Gaps also remain in tailoring effective communication messages to a diversity of audiences and delivering these in local languages. The lack of funding and dedicated budgets for communication constituted a key constraint for public awareness-raising.

5.3 National programmes, legislation and education

A national programme for the conservation and sustainable use of PGRFA is an agreed set of objectives, activities and measures, associated with particular institutions or other structures, to be undertaken at the national level. Four main elements make up an effective national programme: (1) a governmental policy framework and/or strategy for PGRFA conservation and use that provides clear guidance on priorities and implementation actions; (2) governance or coordination by a national entity (a committee, commission, council or board) to provide coherence and efficiency; (3) at least one officially appointed NFP for PGRFA to coordinate activity in the country; and (4) a strong and functioning national information-sharing mechanism for PGRFA that enables the programme to monitor and evaluate progress in the implementation of the GPA2 and share best practices and lessons learned among national actors.

Well-designed and implemented national programmes enable countries to set clear goals and priorities and to effectively allocate resources, assign roles and responsibilities, and identify and strengthen linkages between relevant actors. They promote the implementation of international instruments such as the GPA2, the International Treaty and the CBD by translating global commitments into action at national and local

TABLE 5.1
Reported achievements with respect to national plant genetic resources for food and agriculture programmes, 2012–2019

Type of achievement	Number of countries reporting achievements in this area (out of a total of 79 reporting countries)
PGRFA strategies and legislation	37 countries report some progress in developing PGRFA-specific strategies or relevant legislation; however, the development of strategies and legislation was also highlighted as a crucial gap for many countries
National coordinating entities	21 countries report achievements in establishing or strengthening governance entities to coordinate PGRFA activities at national level
Coherence in national programmes	14 countries report progress in improving the coherence of their national programmes more broadly

Note: PGRFA = plant genetic resources for food and agriculture.

levels. Effective national programmes integrate and unite the diverse actors working with PGRFA in ways that synergize their efforts. Building and strengthening national programmes is a priority activity of the GPA2.

Effective and efficient conservation and use of PGRFA also depend on human resource capacity. Building and strengthening human resource capacity is another priority activity of the GPA2. Critical components of human resource capacity include curators, plant breeders, geneticists, and field and laboratory technicians working in genebanks, botanical gardens and research institutes, as well as farmers and their cooperatives, NGOs, extension workers, policymakers and academics.

This section provides an overview of the state of national programmes and supporting legislation and of education and training provision across the world. Section 5.2.1 presents an analysis of achievements since the publication of the SoW2 across the various elements of national programmes, followed by a more detailed account of differences between regions, including gaps and needs. Section 5.2.2 provides an overview of achievements in the field of training and education at the national level and then presents regional differences.

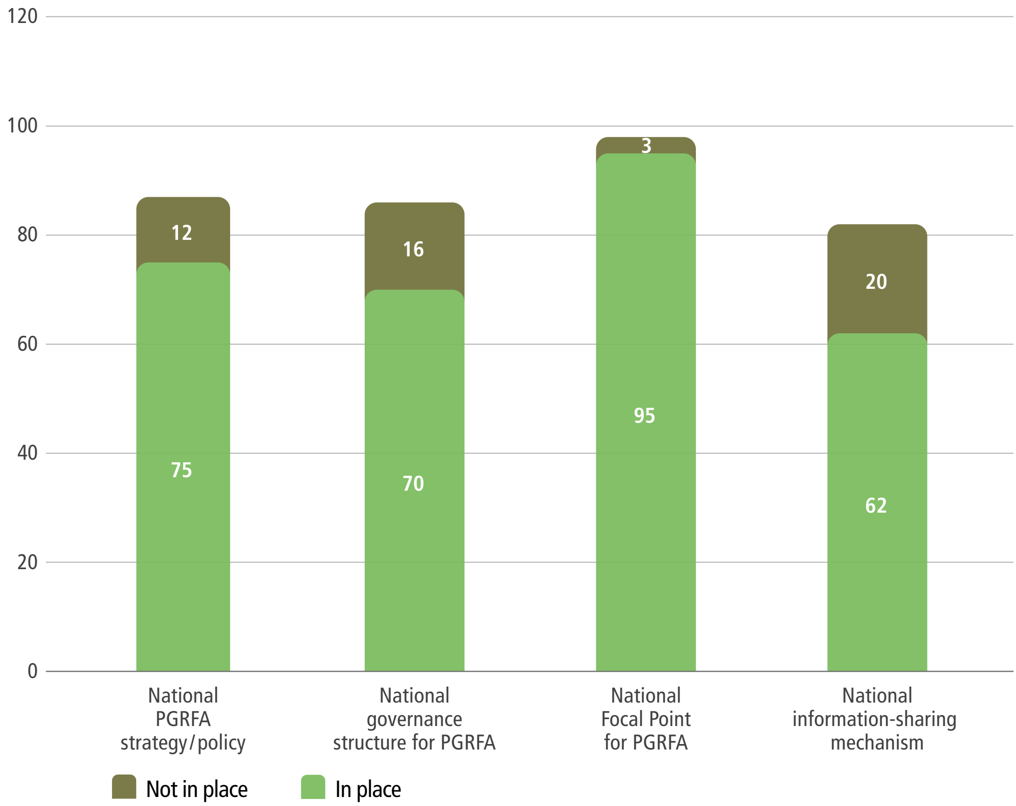
5.3.1 National programmes and supporting legislation for the conservation and sustainable use of plant genetic resources for food and agriculture

Achievements in the implementation of the GPA2 in the context of national programmes are mentioned in country reports from all regions. Key achievements are summarized in Table 5.1.

National policy framework

As illustrated in Figure 5.1, most reporting countries (75 out of a total of 87 countries or 86 percent) indicate that they have a national policy framework or strategy for PGRFA in place. However, only 47 percent of these frameworks have titles that specifically refer to PGRFA or related keywords (e.g. Switzerland's National Plan of Action for PGRFA from 1999), leaving some uncertainty regarding the extent to which the reported strategies target PGRFA specifically. Most of the reported instruments whose titles do not refer to PGRFA are policies that are relevant to PGRFA (e.g. national biodiversity strategies and action plans NBSAPs or seed certification laws) but may not necessarily address PGRFA conservation and use specifically, or if they do may not identify clear pathways for implementation or for the monitoring and evaluation of impacts. Countries that reported NBSAPs (national instruments required under

FIGURE 5.1
Number of countries with elements of national plant genetic resources for food and agriculture programmes in place



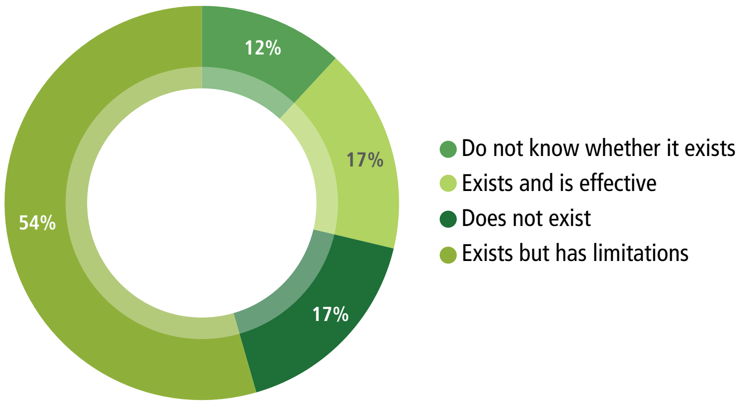
Note: Based on 98 country reports.

Article 6 of the CBD)[5] did not provide details on how exactly these instruments embed PGRFA-specific actions and priorities. A 2016 study of 119 NBSAPs found that only 30 percent included concrete actions on the conservation and sustainable use of PGRFA and that many fewer included plans for the implementation of the International Treaty (Lapena, Halewood and Hunter, 2016).

This tendency for policies to exist without necessarily addressing all PGRFA-relevant dimensions in a comprehensive manner was also reflected in a global survey, targeting a range of stakeholders, conducted by the Secretariat of the International Treaty (Kell, Marino and Maxted, 2017). More than half of the 271 respondents indicated that national policy supporting the sustainable use of PGRFA is in place in the country where they work, but that it does not cover all elements of sustainable use and/or that there are problems with its implementation (Figure 5.2).

[5] Further information at https://www.cbd.int/nbsap/

FIGURE 5.2
Stakeholder responses on national plant genetic resources for food and agriculture policy



Note: The chart summarizes responses to a question answered by 271 respondents to a survey undertaken by the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture in 2015.
Source: Adapted from Kell, S., Marino, M. & Maxted, N. 2017. Bottlenecks in the PGRFA use system: stakeholders' perspectives. *Euphytica*, 213: 1–24.

National governance structure
Most (81 percent) of the 86 countries that reported (Figure 5.1) indicate that they have at least one national entity coordinating PGRFA activities. These include specially constituted committees and already existing institutes, genebanks, statutory bodies and departments within ministries. Occasionally, the role is fulfilled by public–private boards (e.g. the Public–Private Roundtable on Genetic Resources for Food and Agriculture in Chile). Most of these entities meet annually or more frequently.

National focal point
Almost all countries (95 out of 98, or 97 percent) that reported had an NFP for PGRFA in place at the time (see Figure 5.1). While not all the reports provide information on gender, it is encouraging to note that NFPs in all regions include both women and men. NFPs are based in a variety of organizations with relevance to PGRFA, ranging from genebanks and genetic resources or biodiversity institutes to agricultural research centres, agricultural or environmental ministries and seed-industry management units (including phytosanitary agencies).

National Information Sharing Mechanism
The 150 countries that adopted the first GPA in 1996 agreed that its implementation would be monitored and guided by governments and recommended the establishment of a transparent and effective monitoring system. NISMs were one tool for monitoring the implementation of the first GPA, with roles also in improving countries' capacities in exchanging and analysing PGRFA information for future planning and in supporting the coordination of diverse national stakeholders.

While the NISMs established for reporting on the GPA2 have mostly fallen into disuse, information sharing mechanisms are nonetheless needed to support national programmes and enable reporting. Over three-quarters of reporting countries (62 out of 82, or 76 percent) indicate that they have established some sort of information-sharing mechanism for PGRFA (see Figure 5.1). Most of these consist of genebank databases, inventories and biodiversity clearing-house mechanisms – many of which are also cited by countries in the context of information systems (see Section 5.4.1). Even though the content of such information outlets is relevant to PGRFA, they may not on their own be sufficient to enhance the coordination and development of national PGRFA activities. Overall, however, it can be concluded that there has been progress in establishing information outlets of relevance to PGRFA since the publication of the SoW2.

The data provided by countries indicate that some progress was achieved over the reporting period in the development of national PGRFA programmes. However, major shortcomings remain in terms of the quality, levels of implementation and impact of these programmes. There is little evidence that national programmes are enhancing and strengthening conservation and sustainable use of PGRFA to the extent that is necessary in times of climate chaos and biodiversity collapse. Programmes often still lack certain key elements (i.e. appropriate coordination or a dedicated PGRFA strategy) and are generally under-resourced in terms of both budgets and human capacity. In many countries, "national programmes" are more like "institutional programmes" implemented by individual institutions and do not integrate all relevant stakeholders.

Regional assessment

Northern Africa

The Sudan and Tunisia report that they are either developing or revising their NBSAPs. PGRFA-relevant units have been strengthened, and research and development projects with a focus on PGRFA have been developed, as have proposals for national legislation, including biosafety laws. However, both countries cite the lack of a national strategy and the lack of implementation of PGRFA-related legislation as constraints. Human and technical capacity are also highlighted as major gaps.

Sub-Saharan Africa

Six countries across sub-Saharan Africa report that they have revived non-functioning coordinating entities, established new ones or reinforced existing ones. As further detailed in Chapter 3, genebanks have been strengthened in several countries, and PGRFA institutes have been set up or upgraded, including in Kenya, Mali, Nigeria and Zimbabwe. Several countries, including Botswana, Madagascar and South Africa, report that they have drafted PGRFA-specific strategies, and others mention having developed or revised their NBSAPs. Some countries specifically mention strategies focusing on CWR. Uganda highlights that its new PGRFA-related strategies and policies have increased institutional harmonization.

Crucially, more than half the reporting countries in sub-Saharan Africa (58 percent) note that funding shortages need to be addressed before progress can be made in the implementation of the GPA2. Similarly, 47 percent of reporting countries cite shortcomings in the development, finalization or full implementation of their PGRFA strategies or related policies, and some underline the need for technical assistance to overcome these weaknesses, including assistance with harmonizing the implementation of existing policies that conflict with each other.

A few countries highlight failure to address Farmers' Rights. The need to overcome fragmentation and strengthen collaboration is also stressed, particularly collaboration between different government entities but also between government and farmers and breeders. Countries also note the need to address gaps in human and technological capacities and to upgrade infrastructure. Information sharing is reportedly also often poor, and in many cases no information-sharing mechanisms exist at all. A few countries mention the need to strengthen or even establish competent authorities. The country reports also stress that changes of government and volatile politics jeopardize the continuity of programmes even where they are in place.

Northern America

The only Northern American country that reported in detail on the state of its national programme was Canada, which notes that its biodiversity and bioresources science strategy has three PGRFA-related objectives. It also mentions the need to reinstate its Expert Committee on Plant and Microbial Genetic Resources.

Latin America and the Caribbean

The achievement most frequently reported by countries in this region is that they have drafted or adopted PGRFA-relevant policies and legislation or incorporated PGRFA-related priorities into NBSAPs (reported, for example, by Brazil, Costa Rica, Cuba and Nicaragua). The next most frequently reported achievement is the establishment, renewal or strengthening of countries' coordinating or key advisory entities. Collaboration between stakeholders is reported also to have been strengthened. Fewer countries report that they have developed a PGRFA-specific strategy or action plan. A few countries indicate that they have appointed an NFP where one did not previously exist.

A few countries (Brazil, Chile and Mexico) report that they have upgraded or developed their genebank infrastructures or technologies, for example introducing cryopreservation or improving software. Other countries emphasize that public awareness of PGRFA has increased and that the participation and capacity of their rural populations – including of Indigenous Peoples, local communities and women – has increased. They mention that CSBs have been central to this (notably in Guatemala). The collection, conservation and distribution of PGRFA have reportedly been able to continue even in a few countries that cite serious financial difficulties. Two countries (Argentina and Costa Rica) specifically mention achievements related to the International Treaty – ratification and progress in its implementation.

The most urgent need across the region is reported to be addressing the lack of funding or lack of consistent funding (mentioned by two-thirds of reporting countries), followed by developing national programmes and developing or implementing PGRFA-related legislation. Information-sharing mechanisms also need to be set up or strengthened. Capacity building is cited as another significant requirement across the region, as are the establishment or strengthening of national coordinating entities for PGRFA and improving collaboration among diverse stakeholders. Some countries also report the need to improve infrastructure and technology. Some also stress the importance of incorporating FV/LR into legislation, setting priorities for underutilized species and ensuring the inclusion of smallholder and peasant farmers as key actors in PGRFA management.

Asia

In Asia, while only India reports having a strong policy framework in place, many other countries report that they have drafted, revised, developed or adopted a PGRFA-specific strategy or PGRFA-related legislation. Some countries report having improved their NBSAPs, in some cases (including in Armenia, Jordan and Malaysia) by adding a specific strategy for PGRFA or indicators for CWR. Several countries also report having established a governing or coordinating entity for PGRFA-related activities or a new institutional structure supporting PGRFA – for example, the biodiversity thematic research group in Jordan. Two countries report having appointed NFPs for PGRFA, where they did not previously exist. Japan and Mongolia note accession to the International Treaty among their achievements.

Most reporting countries in Asia (11 out of 18, or 61 percent) indicate weaknesses in the development, finalization or full implementation of a PGRFA strategy or related policies. The need to harmonize conflicting policies is also mentioned in this context, as is the need to overcome fragmentation and strengthen collaboration between diverse stakeholders. A lack of sufficient funding ranks as one of the next most frequently reported constraints, alongside the need to establish or strengthen coordinating entities and to build human capacity. A smaller number of countries also mention gaps in information sharing, including a lack of publicly accessible databases, and inadequate infrastructure and technology more broadly.

Europe

Half the European reporting countries note that they have implemented, renewed or drafted specific national PGRFA programmes since the time of the SoW2. Several report having drafted, approved or implemented PGRFA strategies and action plans (including Belarus, France, Hungary and Norway). A few mention that PGRFA-related legislation has been adopted or guidelines published. One country (Hungary) notes that its NBSAP includes an objective related to genetic resources for food and agriculture. A small number of countries (Hungary, Poland, Portugal and Switzerland) report having increased budgets for PGRFA management, something that is not reported in any other region. Several countries (including Estonia, France, Germany and the Nordic countries) report having strengthened coordination among stakeholders.

Funding is at the top of the list of gaps and needs in the region (reported by six countries). However, in contrast to other regions, the challenge is less an absolute shortage of funding than a lack of funding that is sufficiently consistent, stable or long-term to allow PGRFA-related objectives to be achieved. Six countries also report the need to strengthen collaboration and coordination among stakeholders. Several countries report gaps in the development of their national programmes and related legislation: some are non-existent, others need approval or implementation. Similarly, several countries report the need to develop or implement PGRFA strategies and action plans. It is notable that no European countries cite human capacities or infrastructure and technology as gaps or needs. One significant recent development has been the launch of a regional genetic resources strategy (Box 5.1).

Box 5.1
Genetic Resources Strategy for Europe

In November 2021, the overarching Genetic Resources Strategy for Europe was launched. Developed by 17 partners through the GenRes Bridge[a] project to secure genetic resources and enable the region to meet its commitments under global policy frameworks. The strategy is bolstered by individual strategies for plant, animal and forest genetic resources. The Plant Genetic Resources Strategy for Europe was produced by the European Cooperative Programme for Plant Genetic Resources.

Source: ECPGR (European Cooperative Programme for Plant Genetic Resources). 2021. *Plant Genetic Resources Strategy for Europe*. Rome, European Cooperative Programme for Plant Genetic Resources. https://www.ecpgr.org/resources/ecpgr-publications/publication/plant-genetic-resources-strategy-for-europe-2021

[a] Further information at https://www.genresbridge.eu

Oceania

Papua New Guinea reports that commodity institutes have their own national programmes for particular crops. It also indicates that it needs to develop a policy framework for PGRFA, establish a national coordination entity and strengthen human capacities in technology.

5.3.2 Training and education

Most reporting countries indicate that human-resource capacity slightly increased during the reporting period. As illustrated in Figure 5.3, most countries report that they have some kind of educational or training programme in place that covers aspects of the management of PGRFA, mainly at the undergraduate (Bachelor of Science) and postgraduate (Master of Science or Doctorate) levels. However, while PGRFA seem to be increasingly included in educational provision, very few countries have adopted a capacity-building programme specifically dedicated to PGRFA conservation and use, and shortcomings remain in the quality of educational provision. In some countries, programmes and objectives for strengthening technical and institutional capacities in PGRFA conservation and use are developed and implemented in the context of the NBSAPs, for instance in Ecuador, Indonesia, the Republic of Moldova and Sri Lanka.

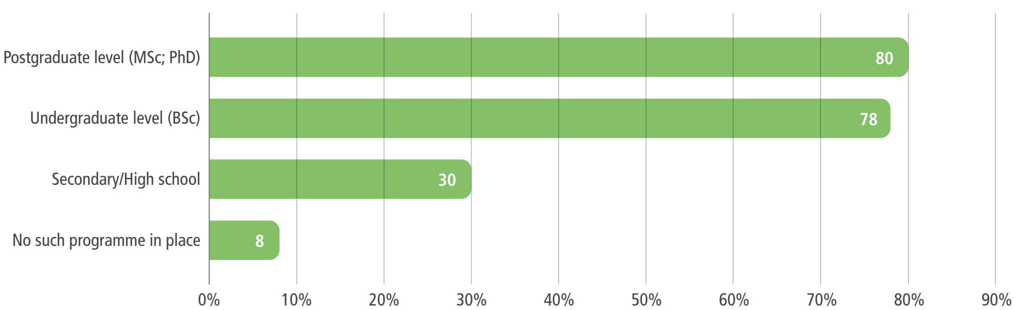
Generally speaking, countries indicate that the diversity of actors involved in training and education was greater during the current reporting period than it was during the reporting period for the SoW2. Universities continue to play a pivotal role in developing and strengthening human resource capacities, conducting research and development projects on PGRFA conservation and use, and operating vocational agricultural schools that provide practical and hands-on approaches to agricultural studies. In addition to academic and educational institutions, an ever-widening array of actors, including botanic gardens, genebanks, seed networks, research centres and institutes, regional and international organizations, NGOs, foundations, associations and museums, also contribute to the development and to strengthening human resource capacity by offering courses, organizing workshops, events and exhibitions, and promoting the exchange of information and experiences.

Thirty-four out of 79 reporting countries (43 percent) report that greater cooperation among and between academic and educational institutions, seed networks, and research centres and institutes, especially with FAO, the CGIAR centres and regional and international genebanks, has led to the implementation of joint and targeted educational, training and research projects, the organization of scientific and practical seminars and conferences and/or the development of exchange programmes for students and teaching staff. For example, many educational institutions offer a greater range of capacity-building opportunities specifically designed for staff of the national PGRFA programme and for farmers, local communities, civil servants and extension agents. However, limited financial resources continue to be an important bottleneck in many countries, hindering access to educational and capacity-building programmes. At the same time, the increasing number of online workshops, seminars and conferences has allowed broader access to some training opportunities. Additionally, innovative teaching materials, including educational videos and online courses and learning resources, have been developed by a range of actors. For instance, the Secretariat of the International Treaty, Bioversity International and UPOV have all developed distance learning courses and training and educational modules.

Reporting countries note there is still a need for greater capacity in education and training and for

FIGURE 5.3

Percentage of countries with different levels of plant genetic resources for food and agriculture-related educational programmes



Note: Based on 90 country reports.

more professional staff specialized in the different areas of PGRFA conservation and use, and that some important gaps and needs remain to be addressed in educational curricula and training programmes. Some countries also express concern about limited financial support and a lack of facilities for training, including a lack of access to updated technologies and information. Figure 5.4 shows the most important capacity-building needs identified across all regions by a global survey conducted in 2015 by the Secretariat of the International Treaty (Kell, Marino and Maxted, 2017).

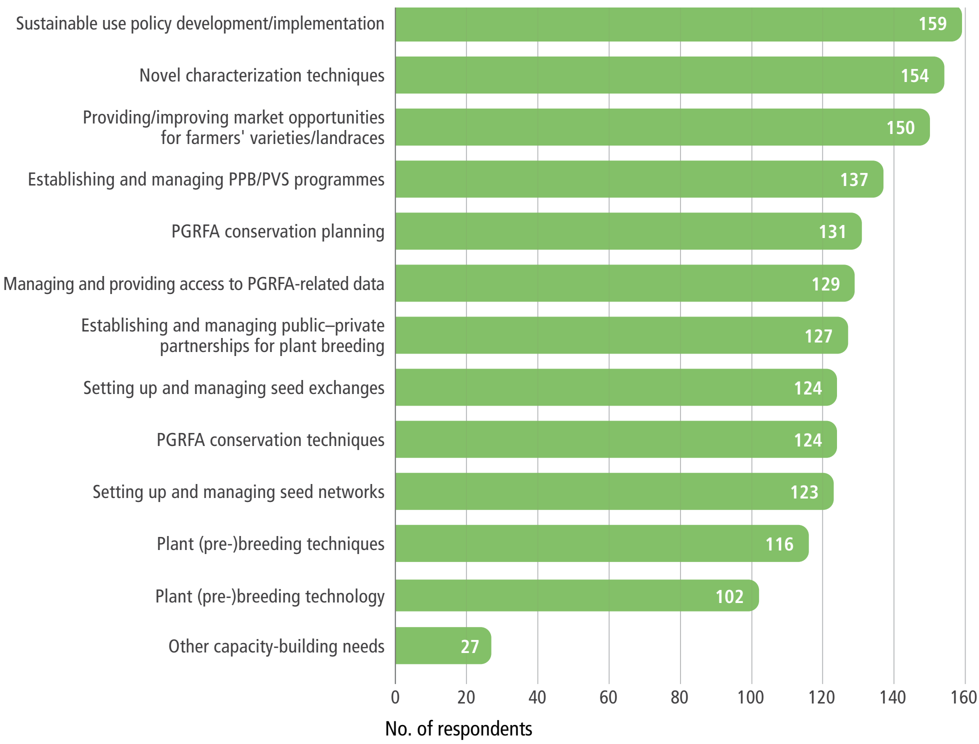
Regional assessment

Northern Africa

Undergraduate and/or postgraduate education programmes on subjects that are relevant to PGRFA conservation and use are reported to be in place in Egypt, Morocco, the Sudan and Tunisia. Egypt and the Sudan report that staff from genebanks and research centres have been trained in various aspects of the conservation and sustainable use of PGRFA, including through workshops organized by the Secretariat of the International Treaty between 2014 and 2019 on the use of genetic markers in

FIGURE 5.4

Capacity-building needs reported by respondents to a survey by the International Treaty on Plant Genetic Resources for Food and Agriculture



Note: Total number of respondents = 245. PPB = participatory plant breeding. PVS = participatory varietal selection. PGRFA = plant genetic resources for food and agriculture.
Source: Adapted from Kell, S., Marino, M. & Maxted, N. 2017. Bottlenecks in the PGRFA use system: stakeholders' perspectives. *Euphytica*, 213: 1–24.

characterization and plant breeding, information networks and exchange, and the registration of DOIs for information systems. Overall, however, countries report that undergraduate and general educational programmes need to be improved and that more training is needed on a variety of topics, especially on advanced technologies.

Sub-Saharan Africa

A large majority of reporting countries from sub-Saharan Africa indicate that their universities offer undergraduate and/or postgraduate educational programmes in subjects related to PGRFA, with some having introduced these subjects in the past decade, for instance Botswana, Eritrea and the Niger. Many countries, including Benin, Ethiopia, Ghana, Madagascar, Mali, South Africa, Zambia and Zimbabwe, mention that these topics are also taught in secondary schools.

Several countries, including Botswana, Ethiopia, Ghana, Kenya, Nigeria, Togo, Uganda, Zambia and Zimbabwe, report that the number of newly trained graduates in relevant topics at MSc and PhD levels has increased, including among the staff of genebanks and research institutes, and that collaboration among universities, genebanks and research centres has increased. In Ethiopia, 223 PGRFA professionals had a PhD and 726 had MSc degrees at the end of the reporting period, up from only, two and five, respectively at the beginning. Some countries report active institutional support for university study, in some cases with international funding (Botswana, Ethiopia and Kenya). Regional educational and training initiatives are described in Boxes 5.2 and 5.3.

In-house training and participation in short-term training courses on PGRFA issues, including variety improvement, biosafety and sustainable use, are reported also to have increased in many countries, for instance in Cameroon, Ethiopia, Guinea, Kenya, Madagascar, Mali, Namibia, Senegal, Togo and Zimbabwe. The numbers of Ethiopian PGRFA professionals who had completed short-term training increased from four at the start of the reporting period to 815 at the end.

Box 5.2

The Regional Universities Forum for Capacity Building in Agriculture

As a network of 157 African universities operating in 40 countries, Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)[a] provides a platform for supporting academic exchanges and collaborative partnerships for promoting linkages with the National Agricultural Research Systems (NARS), the private sector and rural communities, and for strengthening postgraduate training and research. In 2012, RUFORUM and the Centre for Agriculture and Bioscience International (CABI) entered into strategic collaboration to strengthen tertiary agricultural education in Africa.

Since 2015, RUFORUM has been implementing the Graduate Teaching Assistantship Programme, which aims *inter alia* to: improve the quality of higher education and increase the pool of PhD-level academic staff in African universities; provide opportunities for doctoral research to contribute directly to African development; strengthen interuniversity collaboration in the field of higher education in Africa; and promote staff mobility among RUFORUM member universities and across Africa. In addition, with funding from the Carnegie Corporation of New York, RUFORUM–Carnegie supports doctoral alumni for 24-month postdoctoral fellowships based at member universities in Africa; 334 early-career scientists were supported through this initiative. As of 2021, RUFORUM had supported the training of 2 857 students (608 PhD, 2 010 MSc and 239 undergraduate) and the release of more than 300 technologies.

[a] Further information at https://www.ruforum.org/

Despite these developments, important gaps and needs in human resource capacity remain. Gaps are created, inter alia, by shortages of skilled professionals and by staff turnover and difficulties in recruiting young people to replace retiring staff. In several countries, no strategy, policy or national programme for building human capacity is in place. A few countries indicate that they have no academic programme with a PGRFA component in place, in some cases because a

Box 5.3
The African Plant Breeding Academy

Regional plant breeding and biotechnological capacity was boosted by means of a partnership between research centres at different universities across the region and Cornell University (United States), with funding from the Alliance for a Green Revolution in Africa (AGRA). Since its launch in 2013, the African Plant Breeding Academy (AfPBA), an initiative of the African Orphan Crops Consortium (AOCC), has helped 152 plant breeders from 28 African countries to use genomics-assisted approaches to develop improved crop varieties. The fifth cohort of this intensive six-week course for scientists managing plant breeding programmes finished in May 2023. Of the 151 scientists trained, 90 percent have PhDs and nearly 40 percent are women. Collectively, they are working to improve 125 different crops, 60 of which are African orphan crops. The course is delivered by the University of California, Davis (UC Davis),[a] at the World Agroforestry Centre in Kenya (CIFOR-ICRAF). In January 2023, AfPBA introduced a new course on genome editing in agriculture to fast track the engineering of special traits in food crops.

[a] Further information at https://pba.ucdavis.edu/pba-africa

programme of this kind was discontinued during the reporting period. Where they exist, the PGRFA curricula of educational institutions need to be updated on a continuous basis in light of new challenges. Lack of financial resources is a key barrier to accessing training and capacity-building programmes in the region.

Northern America

Canada reports that increased interaction between genebanks and research centres has helped to increase the sharing of knowledge and information. The location of one genebank, Plant Gene Resources of Canada, on the campus of the University of Saskatchewan, has facilitated regular training of its staff. In-person and remote participation in regional and international meetings and conferences have also strengthened human capacities.

Even though the United States did not report on its activities in the field of education and training, its education and training programmes in conservation and use of plant genetic diversity have global outreach. The Plant Breeding Academy at University of California, Davis, which offers classes in Africa, Asia and Europe, is a postgraduate programme teaching the fundamentals of plant breeding, genetics and statistics. The distance education programme in plant breeding at Texas A&M University is a fully online undergraduate degree programme in plant breeding that aims to train future plant breeders worldwide with streamed videos and teleconferencing. Moreover, the GRIN-U collaborative project, developed by the Germplasm Resources Information Network (GRIN) in partnership with the Agricultural Research Service, Colorado State University, Iowa State University and a private contractor, with funding from the USDA National Institute of Food and Agriculture, aims to provide free and open access to educational and training content on PGRFA conservation and use, including videos, virtual tours podcasts, e-books, infographics and manuals.[6]

Latin America and the Caribbean

Reporting countries from Latin American and the Caribbean indicate that, overall, educational and research opportunities in biology and agronomy in the region have greatly increased. New universities and other educational institutions, greater collaboration within and between universities, research centres and extension agencies, at both the national and regional levels, and expansion of research activities have reportedly resulted in a greater number of newly trained graduates in relevant topics. Specialized programmes in biodiversity and PGRFA-related topics are reported to have been established at MSc and PhD levels in Brazil, Cuba, Ecuador, Guyana, Mexico and Nicaragua. Vocational schools are also reported to play an important

[6] Further information at https://grin-u.org

role in the region, for instance in Guyana, where PGRFA-related subjects are taught at the Guyana School of Agriculture, and in Guatemala, where an agrobiodiversity school was established by the Collaborative Program for Participatory Plant Breeding in Mesoamerica in 2016.

Many countries, including Argentina, Brazil, Colombia, Costa Rica, Guatemala, Guyana, Mexico, Nicaragua, Peru, Trinidad and Tobago, and Uruguay, report that capacity was strengthened and/or that the number of qualified personnel involved in PGRFA work increased during the reporting period. As well as providing in-house training, universities, research institutes, NGOs and other extension services are reported to have given courses and workshops for researchers, managers of community seed banks, producers, farmers, local communities, students, civil servants and NGOs on a broad range of topics, ranging from phenotypic characterization and cryopreservation to participatory plant breeding, seed processing and storage, and legal aspects of the exchange and use of PGRFA. Remote participation has enhanced these training opportunities. Cost Rica's National Center for Specialized Organic Agriculture is described in Box 5.4.

Reporting countries from this region also indicate that, alongside formal education, informal institutions such as networks, foundations and social movements have become increasingly important in building and strengthening capacity through the exchange of information, workshops, symposia, technical meetings and debates. Reported examples include the *Sementes da Paixão* (Seeds of Passion) programme in Brazil and the Fundación Salomón in Costa Rica. A few countries, report that they have no strategy, policy or other type of plan in place at the national level for capacity building or that their national policy has not been implemented. Two countries report that they have no PGRFA-related educational programmes. Many countries report that the number of qualified staff at the MSc and PhD levels and the number of trained professionals is insufficient in a range of areas of PGRFA management.

Box 5.4
Costa Rica's National Center for Specialized Organic Agriculture

The National Center for Specialized Organic Agriculture was created by Costa Rica's National Training Institute with the aim of promoting organic agriculture. It has developed didactic projects and eco-productive systems, including the Peasant Seed Rescue Classroom and the Dynamic Bank of Organic Seeds, which runs the House of Seeds project. This project promotes organic agriculture and conserves traditional and ancestral crops, including through the promotion of seeds from Indigenous Peoples and peasants.

Source: Data provided by Costa Rica.

Difficulties in promoting agricultural careers and attracting young professionals are highlighted, as is a lack of financial resources to support education and training.

Asia

All reporting countries in Asia indicate that they have undergraduate and/or postgraduate educational programmes in subjects related to PGRFA. Secondary school-level education on PGRFA-related subjects is reported from Armenia, Azerbaijan, Jordan, Kyrgyzstan and Sri Lanka. Azerbaijan reports that an MSc programme specifically dedicated to the management of PGRFA was established in 2015 at its Genetic Resources Institute and that agreements on joint research activities and staff training were concluded between the Genetic Resources Institute and universities. Armenia mentions that modules on agrobiodiversity, PGFRA conservation and other related subjects are included in the agricultural sciences curricula of several of its universities, at both undergraduate and postgraduate levels, with support from the German Agency for International Cooperation. Capacity-building for the conservation and sustainable use of PGRFA is a strategic axis of Germany's National Strategy and Action Plan on Conservation, Protection, Reproduction and Use of Biological Diversity.

Since the GPA2 was adopted, the number staff members at genebanks and research institutions qualified at the BSc, MSc and PhD levels has increased in many of the region's reporting countries, including in Indonesia, Jordan, Lebanon, Mongolia, Nepal, the Philippines, Türkiye, Uzbekistan and Yemen. Countries also report a variety of local and regional training courses and workshops, operating in person or online, often organized with the support and collaboration of national, regional and international institutions and other partners.

Capacity building in documentation and information systems has been the focus of specific courses, especially after upgrading to GG-CE began in 2019. Staff members of genebanks and research centres in several reporting countries, including Jordan, Mongolia, the Philippines and Yemen, received training in these areas. A regional initiative is described in Box 5.5. However, lack of resources and limited knowledge and expertise among key actors are still challenges in most countries. More staff and higher capacity are needed in many areas of PGRFA management, especially in those involving advanced technologies and those related to policies and legislation. Countries identify the replacement of retiring senior staff and attracting and training young specialists as particularly challenging. The lack of adequate facilities to support research activities is identified as an additional bottleneck. The PGRFA curricula of educational institutions at all levels need to be further developed and updated.

Box 5.5

Genebank Operation Advanced Learning Master Class

The first Genebank Operation Advanced Learning (GOAL) Master Class took place in 2015 in India and gathered participants from national genebanks across the Asia–Pacific region to improve their knowledge and skills in information management, quality control and standard genebank operating procedures. The fifth GOAL Master Class (and last as at the time of writing) was held in 2019 in Viet Nam and placed particular emphasis on information technology and data management in genebanks. GOAL is supported, *inter alia*, by the Global Crop Diversity Trust, Bioversity International and the Indian Council of Agricultural Research.

Source: Crawford Fund for a food secure world. 2019. 2019 GOAL Master Class in Vietnam focussing on IT/Data. *In: Crawford Fund.* [Cited 5 December 2019]. https://www.crawfordfund.org/news/2019-goal-master-class-in-vietnam-focussing-on-it-data/

Europe

Many European countries report a significant increase in the number of students studying PGRFA-related topics and personnel working on PGRFA management, and that their levels of qualification have increased. Courses and modules specifically dedicated to PGRFA conservation and use already existed at the beginning of the reporting period and have continued to be taught in a number of countries, for instance in Finland, France, Italy, the Kingdom of the Netherlands, Norway, Spain, Sweden and Switzerland, with new ones having been established in several countries, including in Albania and the Republic of Moldova. A few countries, including Belarus, France, Italy, the Kingdom of the Netherlands, Spain and Switzerland, report vocational agricultural schools at the secondary level. These schools are reported to train students in a variety of topics, including agronomic botany, plant physiology, crop production, seed production and horticulture, and to enhance their practical skills at training sites. A few countries also report education on PGRFA-related topics at the primary level, for instance in Belarus where 19 ecological centres for schoolchildren have been established. A Swedish initiative is described in Box 5.6.

Countries report that a broader range of online learning materials that offer rich educational resources have been developed. For example, the Natural Resources Institute Finland has made innovative teaching and training material freely available on virtual platforms. In France, a Massive

Open Online Course (MOOC)[7] with a strong component on PGRFA conservation was created in 2019. In the Kingdom of the Netherlands, Wageningen University's MSc programme on plant breeding and its tailor-made professional development courses on PGRFA conservation and use are available online.

About half the reporting countries from Europe indicate that greater collaboration among national universities and research institutes – often the result of the strategic orientation of national plans and strategies and the institutionalization of capacity building – has enabled students to engage in hands-on activities, including practical studies in botanical gardens and national parks, and to undertake internships at genebanks and other scientific and research institutions. For instance, in the Republic of Moldova, where the NBSAP for 2015 to 2020 aimed, *inter alia*, to "develop programs and on-the-job vocational training in public and private sectors in biodiversity conservation", master's students are directly involved in *in situ* and *ex situ* conservation activities as part of their training programmes. In Belarus, university students take part in field trips to conduct research on species diversity in botanical gardens, national parks and scientific centres. This aligns with the country's National Strategy for Conservation and Sustainable Use of PGRFA for 2020–2035 and its concept of the National Strategy for Sustainable Development for the Period up to 2035, which both stress the need for practice-oriented education and strong cooperation between universities and scientific and research institutions. In some countries, technical and managerial staff of genebanks and research centres are reported to be involved in teaching at various levels, and welcome students into their research projects and activities through internships or partnership programmes with universities. Countries also report that a variety of training courses and seminars have also taken place with the support of regional and international organizations, including FAO and ECPGR. They note that important areas for training include plant breeding, database management and information systems such as GRIN-Global. The role of networks in building human capacities has also become increasingly important, for instance in Spain with the Network of Cultivated Universities.[8]

Box 5.6

The Grogrund Centre, Sweden

Created in 2018 at the Swedish University of Agricultural Sciences, the Grogrund Centre acts as a knowledge hub for plant breeding. The centre brings together academia and industry to develop the skills needed to ensure access to plant varieties for agricultural and horticultural production throughout the country in accordance with the objectives of the national food strategy. The Grogrund Centre includes a school that promotes research-based education on plant breeding and food-related disciplines.

Source: Data provided by Sweden.

Despite the positive achievements, countries note that improvements to training in all aspects of PGRFA management continue to be needed. Collaboration among the educational, scientific and research institutes that offer training opportunities needs to be strengthened to improve visibility and better promote training opportunities. Countries also indicate that knowledge transfer at all levels and related to all aspects of the conservation and use of PGRFA, including in the context of generational turnover, remains an important issue.

Loss of knowledge of cultivation practices because of the aging of knowledgeable producers and professionals and the rural-to-urban migration of young people is reported to require special attention. Countries note that traditional knowledge associated with the conservation and

[7] Further information at https://www.mooc.org

[8] Further information at https://reddeuniversidadescultivadas2.wordpress.com/la-red-2/

management of PGRFA is particularly at risk as locally adapted FV/LR become extinct.

Opportunities for the staff of agricultural research institutes to pursue further training, including postgraduate education, reportedly also still need to be improved. Countries mention the need to improve the informal exchange of information, experiences and expertise, for instance through the organization of yearly multistakeholder seminars. Several countries mention the need for additional funding to enhance training opportunities.

Oceania

Australia reports that educational programmes in subjects related to PGRFA are available at the undergraduate and postgraduate levels as well as in secondary schools. Papua New Guinea mentions that the number of staff working at its National Agricultural Research Institute has decreased. Opportunities for the staff of the country's national programme to participate in postgraduate training only exist abroad.

5.4 International collaboration

International collaboration is fundamental to the effective implementation of the GPA2 and other PGRFA-related international instruments, such as the International Treaty, not least because of countries' interdependence in the use of crop germplasm. International collaboration takes a variety of forms, including activities undertaken through PGRFA networks. These networks facilitate the exchange of PGRFA and provide platforms for synergistic collaborations and partnerships that enable the sharing of information, technology transfer, research collaboration, priority setting and the pooling of resources. Promoting and strengthening PGRFA networks is a priority activity of the GPA2. Other forms of international collaboration on PGRFA conservation and use include international agreements that set parameters and guide policy, international initiatives that direct and galvanize action, and funding arrangements that foster and undergird PGRFA-related activity. This section considers the state of these various forms of international collaboration.

5.4.1 Plant genetic resources for food and agriculture networks

Networks may exist at a range of different scales, they may be formal or informal, and they may provide a variety of different benefits to their members. Regional or international networks are of particular importance, as they promote learning across country borders and reflect the high level of interdependence that exists between countries in the use of PGRFA. However, many countries also reported on intranational networks (those at the local level or at the level of subnational regions), indicating the importance of such networks to many different kinds of stakeholders.

The GPA2 urges countries to participate in regional networks and to assist their national stakeholders to participate in crop-improvement networks at any scale. Networks have remained important hubs of activities related to the conservation and sustainable use of PGRFA since the publication of the SoW2.

While some important regional networks, such as the East Africa Plant Genetic Resource Network, (EAPGREN), the Genetic Resources Network for West and Central Africa (GRENEWECA), PROCITROPICOS, REMERFI and CAPGERNET, have had to pause or cease their activities, including because of a lack of financial resources, while others have renewed their efforts, for example the Near East and North Africa Plant Genetic Resources Network (NENAPGRN). Overall, there is consensus that networks of various kinds provide important benefits to their members (Box 5.7). However, the weakening of networks in many regions has meant that these benefits have not been realized in all countries.

A large majority of countries (97 out of 106, or 92 percent; see Figure 5.5) report being part of a network. Apart from specific regional PGRFA networks of the kind listed above, countries report being part of community seed networks

Box 5.7

Key benefits of plant genetic resources for food and agriculture networks as reported by countries

The following list presents the benefits reported across all regions in order of the number of mentions received:

1. knowledge exchange and access to information;
2. capacity building;
3. development of new and/or improved varieties;
4. technology transfer and improved data management;
5. access to and exchange of genetic materials;
6. research partnerships, joint project proposals and funding bids;
7. international collaboration, networking and synergies;
8. characterization and evaluation work;
9. increased numbers of publications and better dissemination;
10. financial support or savings thanks to cost effectiveness or resource pooling;
11. farmer exposure and training;
12. better project design;
13. improved strategy development; and
14. improved conservation.

Source: Based on 73 country reports.

and university networks as well as the CGIAR, the Commission, Crop Trust, the International Treaty and the CBD. These latter international organizations and agreements are not usually understood to constitute the kinds of research and conservation networks discussed in this section. However, from the country reports it is clear that membership of, or engagement with, these organizations provides benefits that are considered important.

Similar figures were reported for the participation of countries' national stakeholders in crop-improvement networks. Ninety-four percent of reporting countries indicate that at least some of their stakeholders are part of crop-improvement networks – only six out of 77 countries report no network membership among their national stakeholders (Figure 5.5).

Information on network membership is reported for a total of 224 stakeholders across 71 countries, with a total of 488 crop-improvement networks cited. Networks are not always named – sometimes reference is just made to individual crops or particular organizations (e.g. CGIAR and UPOV). Botanical Gardens are also mentioned, as are civil society and farmers' seed networks, such as Let's Liberate Diversity[9] and the Farmers' Seed Network (*Réseau Semences Paysannes*).[10] The many networks mentioned include, the East and Central Africa Bean Research Network (ECABREN), the International Network for Genetic Evaluation of Rice (INGER) and the Inter-American Citrus Network (IACNET). The specific stakeholders mentioned in the country reports include research institutes, sometimes crop-specific institutes, genebanks, universities, ministries or research units within ministries, private-sector companies, and foundations (e.g. ProSpecieRara and SAVE Foundation).

Sixty-seven out of 73 countries (92 percent) (Figure 5.5) report that their stakeholders produced at least one publication during the reporting period documenting collaborative activities carried out in the context of PGRFA-related networks (more than 3 780 publications in total). These reports mention a total of 231 stakeholders, 216 of which reported having produced at least one publication of this kind. During the reporting period, countries noted a substantial rise in the number of publications generated through PGRFA network initiatives.

Activities related to the promotion and strengthening of networks were reported across all regions. The main achievements in this field are summarized in Table 5.2.

Regional assessment

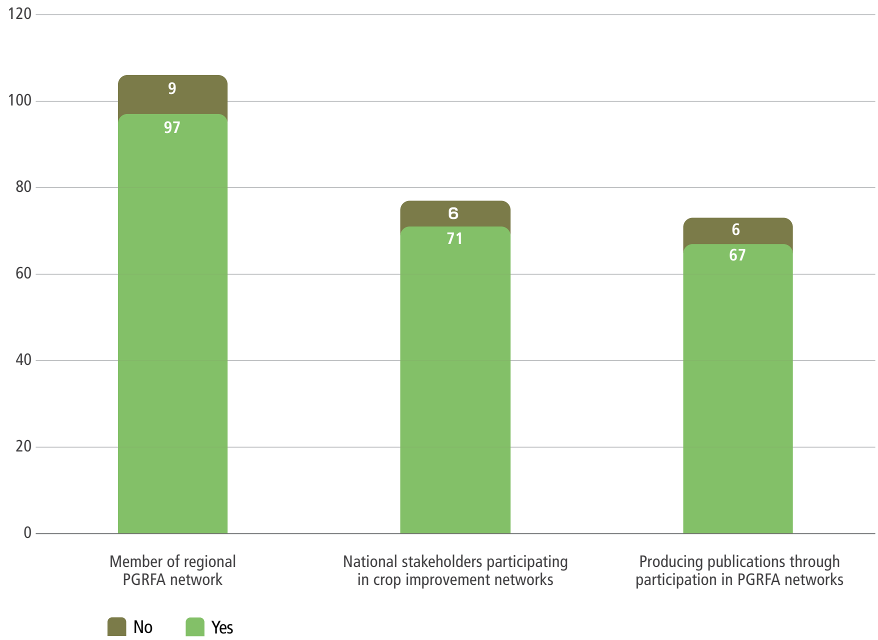
Northern Africa

Egypt, the Sudan and Tunisia report having increased or maintained participation in crop improvement networks and PGRFA collaborations.

[9] Further information at https://liberatediversity.org/

[10] Further information at https://www.semencespaysannes.org/

FIGURE 5.5
Number of countries participating in different categories of international plant genetic resources for food and agriculture networks



Note: PGRFA = plant genetic resources for food and agriculture. Based on 106 countries that reported on this topic.

TABLE 5.2
Achievements reported in the context of strengthening plant genetic resources for food and agriculture networks

Type of achievement	Number of countries reporting achievements (out of a total of 79 reporting countries)
Increased participation in networks overall	40 countries report increasing or maintaining their or their stakeholders' participation in international or regional networks, including for crop improvement; a further seven countries report participating in network-specific working groups or committees; and a further four report consolidating their national networks
Establishment or support of networks focusing on FV/LR or *in situ* work	Eight countries report achievements in terms of supporting networks focused on FV/LR or *in situ* work, often involving the establishment of community seed banks
Development of technology and infrastructure	Seven countries report developing databases, software integration or research infrastructure as contributions to networks or as a result of their participation in networks

Note: FV/LR = farmers' varieties/landraces.

Sub-Saharan Africa

SPGRC's network has been active and become stronger since the publication of the SoW2, some regional networks ceased operations over the reporting period (e.g. EAPGREN and GRENEWECA), leaving gaps in the promotion of PGRFA research and conservation activities. Germplasm exchange was not affected by these developments and continued through crop-specific networks.

Many countries in sub-Saharan Africa (including Botswana, Madagascar, Mali, the Niger, Zambia and Zimbabwe) report that they increased or maintained their participation in crop-improvement networks during the reporting period. They indicate that they improved their germplasm, their knowledge or their techniques through their involvement in such networks, as well as increasing the amount of germplasm conserved *ex situ* and the number of new varieties registered. Countries note that funding for networks is lacking and they also report significant shortfalls in human capacity, especially among government staff and in terms of the capacity to write funding proposals. Some countries indicate that crop-specific networks and collaborations need to be established or improved and some explicitly state that the lack of implementation of their PGRFA strategy has hindered progress in the development of networks. A few countries reported that more and better publications need to be produced in the context of networks.

Northern America

Canada reports continued participation in international networks, cooperation with other countries' genebanks and involvement in PGRFA activities at the global scale. It highlights the need for better procedures for reaching international agreements on PGRFA-related matters.

Latin America and the Caribbean

Most countries in this region report that they participate in international or regional networks and that their national networks were consolidated over the reporting period. Networks within countries are also reported to have been further developed in this region – the Semi-Arid Articulation in Brazil (a grouping of more than 3 000 civil society organizations), the Alliance for Agrobiodiversity[11] in Colombia, which organizes knowledge and germplasm-exchange events for native and FV/LR, and the network of Meso-American community seed banks stand out as non-institutional seed-exchange networks.

However, several regional networks are reported to have declined or ceased their activities (e.g. PROCITROPICOS, REMERFI, CAPGERNET), in some cases because of a lack of finances. Therefore, consolidation and strengthening of networks at all scales is needed. In the absence of sufficient public funding, alternative ways of operating are required, including working with the private sector, an approach that presents its own challenges. Weak national systems and a lack of leadership are reported to constrain improvements to the coordination of existing national networks. Moreover, weaknesses in information sharing mean that there is still a lack of information on national stakeholders' participation in networks. Finally, some countries report that networking is significantly constrained by deficiencies in information technology and internet access.

Asia

Countries across the region report that participation in international networks involving cooperation with CGIAR Centres and other organizations or countries increased or remained steady during the reporting period. Several countries (including Bangladesh, Indonesia and Tajikistan) report that the number of publications increased, that databases were created and that infrastructure improved as result of participation in networks. Crop-specific networks or projects are reported to have led to the creation of new varieties. In some cases, countries report that they have revived networks. Attendance at FAO and International Treaty meetings are highlighted as achievements.

[11] Further information at https://alianzaporlaagrobiodiversidad.semillas.org.co/home/

However, countries note that it remains important to further strengthen collaboration between stakeholders in the management of national and international networks, especially for specific needs (emerging diseases, particular crops, advanced technology). Many countries also mention that a lack of funding is a constraint to participation, specifically the high costs for membership in networks. Human resource capacity is low and information systems and technological infrastructure for knowledge exchange are inadequate.

Europe

Countries across Europe report steady or increased participation in networks during the reporting period, mostly those under the umbrella of ECPGR. Several countries (including Albania, Estonia, Finland, France, Germany, the Kingdom of the Netherlands, Latvia, Portugal and Switzerland) highlight their membership in network-specific working groups or committees and the development of software integration or research infrastructure as a result of networking activities over the reporting period. Networking also led to the establishment of CWR reserves and to the strengthening of *in situ* conservation work, CSBs and specially curated genebank collections. Generally, national networks have been promoted and strengthened and funding has been provided for them.

Despite the progress made, countries note that there is a need to strengthen regional coordination and increase financial support for networking. They point out that because networks are generally based on voluntary work, they tend to be fragile and dependent on project funds. They also note that information sharing needs to be improved and that more stakeholders need to be involved. The lack of a regional network on CWR is highlighted, as is the lack of a coordinating organization at the regional level.

Oceania

Papua New Guinea reports continued participation in international networks and accession to the International Treaty as key achievements. The Pacific Agricultural Plant Genetic Resources Network (PAPGREN) continues to support its 27 member countries.

5.4.2 Intergovernmental agreements and initiatives

The importance of crop diversity, CWR and wild food plants (WFP) to sustainable production, nutritious and sustainable diets, the livelihoods of smallholder farmers and the resilience of agricultural systems to climate change is increasingly recognized at the international scale. The International Treaty (see Section 5.5) remains the central international agreement providing a framework for the management and exchange of PGRFA. Since the publication of the SoW2, the conservation and sustainable use of PGRFA, along with ABS, have been prioritized by several other international agreements and initiatives (IPBES, 2019). However, many global goals and targets related to safeguarding biodiversity, have not been met within their timeframes, and worries about the state of the world's biodiversity are mounting (IPBES, 2019).

A crucial question in this context, is how can international agreements be effectively transformed into action? Apart from political will, this will require effective institutional support and inclusive processes for devising actionable strategies. Similarly, the capacities of actors on the ground need to be strengthened, including local governments, civil society organizations, Indigenous Peoples, local communities and their networks, all of which have been at the forefront of crucial and often neglected aspects of GPA2 implementation. This section identifies key international agreements and initiatives, other than the International Treaty (see Section 5.5), that have been developed or gained in significance since the publication of the SoW2.

Convention on Biological Diversity, biodiversity plans and Aichi Targets

2011 to 2020 was the UN Decade on Biodiversity. The CBD's Strategic Plan for Biodiversity 2011–2020 and its Aichi Targets[12] as well as the Global Strategy for Plant Conservation 2011–2020 (CBD, 2012) cemented the focus on cultivated plants and WFP and on CWR.

Aichi Target 13 focused on the maintenance of the genetic diversity of cultivated plants, farmed and domesticated animals and wild relatives. Indicators for assessment included the number of PGRFA conserved *ex situ* and expenditure in the context of genetic conservation. *The Global Biodiversity Outlook 5* (GBO5) (CBD, 2020) – a periodic report on the state of the world's biodiversity prepared under the auspices of the CBD – demonstrated that while 74 percent of countries' NBSAPs contained targets related to Aichi Biodiversity Target 13, less than one-fifth of countries had set targets similar to (18 percent) or exceeding (1 percent) the scope and level of ambition of the global target. Most national targets referred to the conservation of genetic diversity in general but did not consider the specific elements set out in Aichi Target 13. In particular, the conservation of CWR and strategies to minimize their genetic erosion were not included in countries' national targets.

While about one-third of countries reporting to the CBD on progress towards their national targets stated that their targets were on track to be met (30 percent) or exceeded (5 percent), a larger number (49 percent) had made insufficient progress and targets were therefore not met in time. Moreover, almost one-fifth (17 percent) reported that they had made no progress at all. Only 8 percent of reporting countries had national targets of similar scope and ambition to Aichi Biodiversity Target 13 and were on track to meet them. According to the GBO5, countries reported that the key constraints to reaching this target were biases towards conservation programmes for certain crop species and a lack of financial and human resources for conservation.

Nagoya Protocol

Having been adopted in 2010, the Nagoya Protocol of the CBD entered into force in 2014. While the objectives of both the CBD and the International Treaty are the conservation and sustainable use of genetic resources and the equitable sharing of benefits arising from their use, the ABS systems established under the International Treaty and the Nagoya Protocol are different. The International Treaty takes a multilateral approach (presented in more detail in Section 5.5), while the Nagoya Protocol creates bilateral mechanisms.

Over recent years, cooperation between the secretariats of the two instruments increased and various stakeholders have taken action to support countries in their efforts to improve and harmonize their ABS-related measures. Developments since the publication of the SoW2 have included the following:

joint capacity-building workshops conducted by the secretariats of both international instruments under the GEF-funded project for the early entry into force of the Nagoya Protocol (2011–2012);

- a series of "tandem" workshops (2014–2018) that paired focal points of the two international instruments from individual countries to work together on the challenge of ensuring coherence and mutual support;
- a Darwin Initiative-funded project (2015–2018) for mutually supportive implementation in Benin and Madagascar; and
- a "tandem" workshop organized under the UNDP-GEF Global Access and Benefit-sharing Project (2016–2021).

2030 Agenda for Sustainable Development and the Sustainable Development Goals

In 2015 the UN General Assembly adopted the 2030 Agenda for Sustainable Development (2030 Agenda), with its 17 SDGs and 169 associated targets. The conservation and sustainable use of PGRFA are addressed under Target 2.5 and Target 15.6.

Target 2.5 (under SDG 2 Zero Hunger) specifically concerns the conservation of genetic diversity, including PGRFA. The plant component of Target 2.5 is monitored by Indicator 2.5.1.a, "Number of plant genetic resources for food and agriculture secured in either medium or long-term conservation facilities." SDG 2.5.1.a, which

[12] Further information at https://www.cbd.int/sp/targets/

TABLE 5.3
Kunming-Montreal Global Biodiversity Framework targets with special relevance to plant genetic resources for food and agriculture

Target	Relevance to plant genetic resources for food and agriculture
4	Target 4 concerns conservation and restoration of genetic diversity, including through *in situ* and *ex situ* conservation and sustainable management practices.
10	Target 10 concerns the sustainable management of areas under agriculture, aquaculture, fisheries and forestry, in particular through the sustainable use of biodiversity.
13	Target 13 concerns facilitated access to genetic resources and associated traditional knowledge and equitable sharing of benefits arising from their use, as well as the use of digital sequence information on genetic resources.
14	Target 14 concerns the integration of biodiversity values into all policies and regulations across all sectors and levels of government and into financial flows.
19	Target 19 concerns increasing financial resources to meet implementation needs.
20	Target 20 concerns strengthening capacity and access to technologies and innovations for biodiversity management.
21	Target 21 concerns the promotion of awareness, education and research to ensure that biodiversity management is guided by relevant knowledge, including the traditional knowledge of Indigenous Peoples and local communities when provided with their free consent.
22	Target 22 concerns full participation in decision-making on biodiversity by Indigenous Peoples and local communities as well as by women and youth and persons with disabilities.

Source: CBD (Convention on Biological Diversity). 2024. 2030 Targets (with guidance notes). [Cited 19 December 2024]. https://www.cbd.int/gbf/targets.

is part of the global indicator framework adopted by the United Nations General Assembly in July 2017 (UN General Assembly, 2017) to monitor the implementation of the SDGs, is a Tier I indicator.[13] Monitoring of country reporting on SDG 2.5.1.a started in 2014 as part of the monitoring of the implementation of the GPA2, and since 2016 it has been undertaken on an annual basis. The geographical coverage of the indicator increased from 71 countries in 2014 to 116 in 2022.

Target 15.6 (under SDG 15 Life on Land) concerns the promotion of access to genetic resources and benefit-sharing arising from their use, a key indicator of which is the number of countries that have adopted legislative frameworks to ensure fair and equitable benefit-sharing. The data-collection methods for the indicators refer to countries' efforts in implementing the International Treaty and the Nagoya Protocol (United Nations, 2024). As of 2021, 67 countries had reported to the Access and Benefit-sharing Clearing-House of the CBD that they had put in place legislative, administrative and policy frameworks or measures to ensure the fair and equitable sharing of benefits.

According to the *Sustainable Development Report 2022* (United Nations, 2022), cascading and interlinked crises are putting the 2030 Agenda in grave danger, along with the very survival of humanity. It notes that there are severe challenges ahead associated with a confluence of crises, dominated by the COVID-19 pandemic, climate change and conflicts.

Kunming-Montreal Global Biodiversity Framework

The goals and targets of the Kunming-Montreal Global Biodiversity Framework (CBD, 2022a), adopted at the 15th Conference of the Parties to the CBD, held in Montreal, Canada, in December 2022, undergird increased action on PGRFA. The framework is intended to go beyond the CBD and its protocols and to be of relevance to all biodiversity-related international agreements. As shown in Table 5.3, eight targets are associated particularly closely with implementation of the GPA2.

[13] An indicator with an internationally agreed methodology and a global reporting rate equal to or higher than 50 percent.

5.4.3 Other international initiatives

Svalbard Global Seed Vault

In 2008, the Government of Norway established the SGSV[14] in Svalbard, in the Arctic Circle, which provides a secure and controlled environment (–18 °C) as a safety backup for *ex situ* collections. The International Treaty provides the international legal framework for the seed vault, which is managed by a partnership between the Norwegian Ministry of Agriculture and Food, NordGen and the Crop Trust. As of December 2022, almost 1.2 million seed samples from 93 genebanks located in 70 different countries, and representing about 6 000 plant species, were stored in Svalbard. Twelve of the current 93 depositors are international agricultural research institutes, including CGIAR centres, 73 are national genebanks and universities, two are regional genebanks and five are NGO genebank collections. One of the depositors is a private company that has deposited seeds in cooperation with the Government of Singapore.[15]

CGIAR

Eleven CGIAR centres signed Article 15 agreements with the Governing Body of the International Treaty in 2006. Taken together, CGIAR genebanks represent the largest and most widely used collections of crop diversity in the world. As of 31 December 2021, these centres conserved and made available, using the International Treaty's SMTA, a total of 722 525 accessions of crop, tree and forage germplasm. In addition, the centres maintain approximately 17 000 accessions that are not available under the International Treaty's multilateral system, as they are maintained under black box or other legal conditions that do not allow their distribution with the SMTA. During 15 years of operation within the framework of the International Treaty (January 2007 to December 2021, inclusive), CGIAR centre genebanks and breeding programmes distributed more than 6 million PGRFA samples under 61 000 SMTAs (FAO, 2022a).

From 2017 to 2021, the CGIAR Genebank Platform, coordinated by the Crop Trust, supported the core activities of the CGIAR genebanks, conserving and making available crop and tree genetic resources, by ensuring that the genebanks meet international standards in compliance with the International Treaty. In 2019, the CGIAR embarked on a system-wide reform (towards "One CGIAR") with a view to increasing efficiency and effectiveness in response to evolving global challenges. One CGIAR brings all CGIAR centres together under a single, cohesive structure intended to make better use of the centres' capabilities (CGIAR, 2021). In the context of this reform, the CGIAR Genebank Initiative, which arose from the former CGIAR Genebank Platform, aims to implement technological advances and institutional measures that improve the *ex situ* conservation of PGRFA globally. Aside from conservation, CGIAR centres also engage in breeding programmes for some of the world's most widely cultivated crops.

Other international agricultural research networks

Alongside the CGIAR, other international agricultural research and innovation networks have made crucial contributions to global efforts to conserve and sustainably use PGRFA. Although they cannot all be listed here, some examples can be provided.

The Association of International Research and Development Centres for Agriculture (AIRCA) groups seven key international agricultural research centres in an alliance focused on increasing global food security through climate-resilient food systems and enhancing the work of individual centres.

Jointly established by FAO, IFAD, the World Bank and the CGIAR in 1996, the Global Forum on Agricultural Research and Innovation (GFAR) unites more than 600 partner organizations across several sectors, bringing together scientific research organizations, educational organizations, extension services, development agencies, the private sector,

[14] Further information at https://www.seedvault.no/

[15] Information on depositors obtained via email exchange with NordGen.

and representatives of farmers and civil society. With the aim of enhancing the contribution that agrifood research makes to the achievement of the SDGs, GFAR partners advocate for and catalyse multistakeholder programmes of work that include producers and focus on women and youth. GFAR has co-organized three iterations of the Global Conference on Agricultural Research for Development (GCARD) (in 2010, 2012 and 2015/16).

Regional agricultural research networks also play crucial roles in advancing knowledge and action in the field of PGRFA conservation and use. The Forum for Agricultural Research in Africa (FARA),[16] which serves as the technical arm of the African Union Commission, coordinates and advocates for agricultural research for development across Africa and brings together regional associations such as the West and Central African Council for Agricultural Research and Development (CORAF/WECARD),[17] the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)[18] and the Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA).[19] Since 2010, the African Union programme African Biosafety Network of Expertise (ABNE)[20] has been working with regulators and policymakers across Africa to enhance countries' regulatory systems in the field of biosafety. It also provides technical services to African Union member countries with respect to international agreements, including the International Treaty and other agreements discussed above.

Since 1990, the Asia–Pacific Association of Agricultural Research Institutions (APAARI)[21] has been working to catalyse collaborations that strengthen agrifood research and innovation systems for sustainable development in the Asia–Pacific region. It brings together countries, universities, national and international agricultural research centres, civil society organizations, and subregional and regional fora – including FARA and the Asia and Pacific Seed Association (APSA).

The Association of Agricultural Research Institutions in the Near East and North Africa (AARINEN)A[22] promotes and facilitates the development of state-of-the-art transformational solutions that enable the region's agricultural research and innovation systems to address critical and pressing agricultural and innovation challenges more effectively. It focuses on mobilizing dialogue, knowledge exchange and partnerships over collective actions; empowering rural women, youth and smallholder farmers; improving policies; and strengthening capacities of agricultural and innovation systems. The Arab Organization for Agricultural Development (AOAD)[23] identifies and develops linkages among Arab countries, and coordinates agricultural and agriculture-related activities among them.

The Technical Cooperation Network on Plant Biotechnology in Latin America and the Caribbean (REDBIO)[24] promotes the development and use of biotechnology in the region. Founded in 1990 at an FAO meeting, it has been working independently of FAO since 2011 to disseminate knowledge and promote regional cooperation and projects, with a special focus on agricultural innovations. Every three years, REDBIO organizes scientific conferences, which have gained considerable visibility and consolidated biotechnological research in the region.

Several of the cooperative programmes on research and technology transfer under the Inter-American Institute for Cooperation on Agriculture continue to provide considerable support to their members, most notably the Cooperative Program for Technological Development in Agriculture in the Southern Cone (PROCISUR) and the Cooperative Program in Research and Technology for the Northern Region (PROCINORTE).

16 Further information at https://faraafrica.org/
17 Further information at https://www.coraf.org/
18 Further information at https://www.asareca.org/
19 Further information at https://www.ccardesa.org/
20 Further information at https://www.nepad.org/programme/african-biosafety-network-of-expertise-abne
21 Further information at https://www.apaari.org/
22 Further information at https://aarinena.org
23 Further information at https://www.aoad.org/Eabout.htm
24 Further information at https://redbio.net/redbio-internacional/

Non-governmental and civil society organizations and networks at the international level

Organizations and networks in the civil society sector have also increased in number and influence since the publication of the SoW2. The Gene Campaign,[25] the Action Group on Erosion, Technology, and Concentration (ETC Group)[26] and GRAIN,[27] all of which were mentioned in the SoW2, have continued and strengthened their PGRFA-related activities. Several new actors can be added to this list, as their influence has increased significantly over the intervening period. For example, the international peasant movement La Via Campesina,[28] which celebrated "30 years of struggle" in 2023, has become an increasingly strong voice in international fora, representing its large constituency of smallholder associations, organizations of Indigenous People, local communities and other food-producers' networks. It has put forward demands for food and seed sovereignty as crucial elements of the realization of Farmers' Rights and has made the plight of FV/LR more visible.

International seed saver networks have also gathered strength and expanded their member bases and work programmes. Notable examples include the Seed Guardians Network (*Red de Guardianes de Semillas*),[29] Seed Savers Network,[30] the Farmers' Seed Network (*Réseau Semences Paysannes*)[31] and the Gaia Foundation's International Seed Network Exchanges[32] initiative, all of which focus on conserving locally adapted and often ancestral or culturally significant crop diversity in farmers' fields and in CSBs.

Launched at the 2002 World Summit on Sustainable Development in Johannesburg, the programme on Globally Important Agricultural Heritage Systems (GIAHS)[33] covered 89 sites in 28 countries in 2024, with continuing applications for further designations. By promoting policies and incentives to support the conservation and sustainable development of GIAHS and their associated landscapes, local cultures and traditional knowledge, the programme aims to enhance the resilience of these important sites, including through a focus on locally adapted PGRFA. It was officially endorsed as an FAO regular programme in 2015.

5.4.4 International funding mechanisms

In 2019, a study commissioned by the International Treaty indicated that if funding made available through multilateral organizations, bilateral agreements, public institutions at the national level and the private sector is taken into account, global investments in PGRFA activity ranges from USD 12 billion to USD 14 billion per year (Caracciolo, 2019). The same study developed several scenarios for the successful implementation of the GPA2 and calculated that the funding gaps needing to be covered in order to achieve them were approximately USD 600 to 700 million per annum. A 2015 study by FAO, IFAD and the World Food Programme similarly indicated that USD 977 million (at 2017 prices) in additional rural investment in developing areas would be required per year for activities related to the preservation and improvement of crop genetic resources within a set of activities required to sustainably end hunger by 2030 (FAO, IFAD and WFP, 2015). Yet public spending on the management of genetic resources has steadily decreased over the last few decades (Smyth, Webb and Phillips, 2021) and, while private foundations and private–public partnerships have to some extent filled this gap, both national and international initiatives increasingly depend on finding innovative ways of mobilizing resources.

The Crop Trust, established in 2004, remains the pivotal mechanism for providing long-term

[25] Further information at https://genecampaign.org/
[26] Further information at https://www.etcgroup.org/
[27] Further information at https://grain.org/
[28] Further information at https://viacampesina.org/en/
[29] Further information at https://redsemillas.org/english-seed-guardians-network/
[30] Further information at https://seedsaverskenya.org/
[31] Further information at https://semencespaysannes.org
[32] Further information at https://www.seedsovereignty.info/
[33] Further information at https://www.fao.org/giahs/en/

sustainable funding for the conservation of PGRFA. Its endowment fund has grown from the USD 150 million cited in the SoW2 to USD 340 million at the end of 2022, a considerable achievement that has also led to an increase in the number of genebanks supported. Since 2018, the Crop Trust has been funding the IRRI in perpetuity through a long-term partnership agreement. Its long-term grants also cover, in perpetuity, a proportion of the conservation costs of 20 internationally important PGRFA collections. Over the last decade, the Crop Trust has also successfully attracted new funding from sources that have not previously been available for work on PGRFA and has placed greater emphasis on supporting national genebanks.

However, Crop Trust calculations show that despite the growth of the endowment fund, another USD 500 million are needed to safeguard PGRFA diversity *ex situ* in perpetuity. To raise these additional funds, the Crop Trust has been working on developing a new financing strategy since 2021 to increase its income from traditional donors such as national governments and foundations as well as to establish innovative finance mechanisms to attract greater contributions from the private sector and individuals. The Emergency Reserve for Genebanks established by the Crop Trust and the Secretariat of the International Treaty is described in Box 5.8.

In 2017, the Governing Body of the International Treaty decided to update its funding strategy with a view to adopting a programmatic approach that would strengthen linkages between different funding sources and partners relevant to the International Treaty by pursuing collaborative planning and co-spending opportunities and identifying and using appropriate channels to make such linkages. The funding strategy's overarching aim is to mobilize funds "for priority activities, plans and programmes, in particular in developing countries and countries with economies in transition, and taking the Global Plan of Action into account" (Article 18.3), especially in order to assist farmers to conserve and sustainably use PGRFA.

Box 5.8
Emergency Reserve for Genebanks

Recognizing that genebanks are not indestructible and are just as prone to disasters and catastrophes as other vital infrastructure, the Global Crop Diversity Trust (Crop Trust) and the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture jointly launched the Emergency Reserve for Genebanks in November 2021. While the Crop Trust had previously supported genebanks in emergencies, for example by contributing to the safeguarding of seeds threatened by the civil war in the Syrian Arab Republic in 2011, providing finance to restore the seed-drying facility of the genebank of the Philippines after it had been damaged by flooding in 2019 and replacing the generator of the genebank of Yemen, the new Emergency Reserve will be the world's first dedicated fund for urgent provision of financial support to genebanks under imminent threat from natural disasters, political conflict, pest and disease outbreaks, technological failure or other emergencies. The Governments of Italy and Norway were initial donors.

Sources: Crop Trust. 2024. Emergency Reserve for Genebanks. [Cited 9 December 2024] https://www.croptrust.org/work/emergency-reserve-for-genebanks/; International Treaty on Plant Genetic Resources for Food and Agriculture and the Global Crop Diversity Trust. 2021. *An Emergency Reserve for Genebanks - Operational Framework*.

Importantly, since the publication of the SoW2, a funding target of USD 1 billion per year has been established with the objective of ensuring adequate financing for the implementation of the International Treaty and generating funding for its various mechanisms, including its Benefit-sharing Fund. The Benefit-sharing Fund is discussed in more detail in Section 5.5.1. The funding target is intended to allow a high level of implementation to be achieved for all the priority activities of the GPA2 by 2030, and the methodology used to determine the target (Caracciolo, 2019) drew on the monitoring process for the GPA2, thus strengthening the mutual interrelation between the International Treaty and the GPA2. The International Treaty's

Funding Strategy furthermore foresees the development of monitoring processes that would involve periodic reviews of financial flows to areas of International Treaty implementation. Information derived from such monitoring processes could inform future iterations of *The State of the World's Plant Genetic Resources for Food and Agriculture*.

While quantitative figures were impossible to obtain, the information presented in

TABLE 5.4

Key funding channels and mechanisms supporting different areas of plant genetic resources for food and agriculture activity

Area of activity	Key funding channels and mechanisms
Ex situ conservation	The two international institutions leading efforts in funding *ex situ* conservation are the Crop Trust and the CGIAR. These institutions ensure funding to genebanks at the global level. The World Bank and the Bill and Melinda Gates Foundation are among the key donors to the CGIAR centres. The Crop Trust is the only institution that has reported specific funding for CGIAR collections and that has a long-term programmatic approach to supporting these collections. CGIAR collections also receive funding from bilateral or regional programmes on a more ad hoc basis. Core funding for national *ex situ* collections comes from national budgets. While there appears to be no leading multilateral channel for the provision of support to national *ex situ* collections, these collections receive funding on an ad hoc basis under individual projects through multilateral and bilateral channels.
In situ conservation/ on-farm management	There is strong indication that the main multilateral channel through which support flows specifically to *in situ* conservation efforts and crop wild relatives (CWR) is the Global Environment Facility (GEF). Other actors such as the International Fund for Agricultural Development (IFAD) and the CGIAR contribute to some extent to *in situ* conservation, specifically to research in this field. On-farm management is one of the main priorities of the Treaty's Benefit-sharing Fund, and there are specific GEF programmes supporting this area of activity. GEF projects on biodiversity conservation also promote the *in situ* and on-farm conservation of crop diversity through awareness raising and capacity building among farmers, Indigenous Peoples and local communities, and local and national institutions. Many IFAD grants focus on on-farm management coupled with crop diversification and market value chains, and the same holds for projects funded by the Green Climate Fund. While the CGIAR may often be seen as a leader in *ex situ* conservation and breeding, a considerable amount of funding has also been channelled through the CGIAR to support on-farm management, especially through aspects of their research programmes (CRPs), which were part of the 2017–2022 portfolio.
Breeding/sustainable use	The CGIAR channels considerable amounts of funding towards the breeding of the crops listed in Annex 1 of the Treaty. Many regional breeding initiatives have been funded by bilateral programmes or foundations. The World Bank and the regional development banks play significant roles in this context, as does the private sector. Where support for other areas of sustainable use is concerned, crop diversification, markets and seed delivery are frequently included in projects funded by the GEF, the Green Climate Fund, IFAD and the Treaty's Benefit-sharing Fund. The sixth and seventh GEF replenishment cycles included specific objectives on sustainable use. FAO has a long tradition of support for projects focused on seed systems and seed policies.
Information systems	The main resource partners for PGRFA information systems are FAO, the Crop Trust, the CGIAR, the United States Department of Agriculture and certain donors to the Treaty's Fund for Agreed Purposes. These are the key entities that contribute financially to maintaining the global information infrastructure, including the systems detailed in Section 5.4.1. The national and regional programmes that contribute data to global systems and manage their own information systems receive funding mainly from national sources. Resource partners for biodiversity information, including information on wild PGRFA occurring *in situ*, are the Global Biodiversity Information Facility (GBIF) and the International Union for Conservation of Nature (IUCN).
Access and benefit-sharing	Funding to support the Treaty's Multilateral System (MLS) is channelled primarily through (i) the funding provided to the global, regional, and national genebanks that sustain the MLS, that is mainly through the Crop Trust, the CGIAR and national sources, and (ii) the policy and capacity-building programmes that the CGIAR and the Treaty's Fund for Agreed Purposes support to facilitate developing countries' participation in the MLS. The GEF has financially supported the implementation of the Nagoya Protocol in harmony with the Treaty, as has the United Kingdom's Darwin Initiative. The Treaty's Benefit-sharing Fund is a key channel for sharing monetary benefits arising from the use of materials in the MLS (see Section 5.5.1 for more details).
Farmers' Rights	There are no known funding mechanisms that specifically prioritize Farmers' Rights (Farmers' Rights are discussed in more detail in Section 5.5.2). However, while very limited ad hoc funding is provided by some donors through the Treaty's Fund for Agreed Purposes, on-farm management projects regularly have policy and capacity building components that relate to the implementation of Farmers' Rights.

Note: The information presented draws heavily on a background study conducted in two iterations between 2018 and 2019 by the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture to inform the process of updating its Funding Strategy.
Source: FAO. 2019. *Preparation of country reports* for The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Rome. https://www.fao.org/pgrfa/resources/openDocs/Reporting_Guidelines_2020e.pdf.

Table 5.4 indicates the key funding channels and mechanisms that support different areas of PGRFA-related activity.

5.5 Information systems and monitoring mechanisms

For PGRFA diversity to be of use to plant breeders and farmers, information about their characterization and subsequent evaluation is essential. The GPA2 envisions effective information systems for managing data on *ex situ* collections, and on CWR and FV/LR conserved *in situ* and on-farm, and for making these data publicly available, along with as much relevant associated information as possible. New varieties released nationally are also meant to be documented and the documentation made publicly available. The more stakeholders participate in these information systems by contributing, accessing and exchanging data, the stronger the systems become. Priority Activity 15 of the GPA2 focuses on constructing and strengthening comprehensive information systems. Exchange of information is also a key element of the International Treaty's Article 17, which requires that Contracting Parties "cooperate to develop and strengthen a global information system to facilitate the exchange of information."

The importance of genetic diversity is increasingly being recognized, as is the fact that systematic monitoring of this diversity is key to its conservation and sustainable use (Thormann and Engels, 2015). Genetic erosion occurs in farmers' fields and in the wild, as well as in *ex situ* collections.[34] The SoW2 concluded that better techniques and indicators for establishing baselines and monitoring trends in genetic diversity were needed. A key objective of the GPA2 is to minimize genetic erosion and its impact on sustainable agriculture through effective monitoring of genetic diversity, the drivers of genetic erosion and the implementation of remedial or preventive actions. Similarly, the need to monitor genetic diversity is reflected in the Kunming-Montreal Global Biodiversity Framework, particularly Target 4 "Halt Species Extinction, Protect Genetic Diversity, and Manage Human-Wildlife Conflicts" and the identified indicators, among these SDG 2.5.1.a.[35]

This section first presents findings on the state of information systems documenting PGRFA *ex situ* and *in situ* and then discusses the state of monitoring mechanisms for genetic erosion.

5.5.1 Information systems for plant genetic resources for food and agricultures

The SoW2 noted that there had been an overall improvement in the accessibility of information since the publication of the SoW1. However, there was a significant imbalance between regions and even between countries within regions. Overall, the documentation and characterization of many collections was still inadequate, and in the cases where information did exist, it was often difficult to access. The SoW2 concluded that greater efforts to build a functional global system of *ex situ* collections were needed and that this, in turn, required stronger regional and international trust and cooperation. The need for greater standardization of data and data management was also acknowledged.

Since the publication of the SoW2, DOIs and multicrop passport descriptors (MCPDs) have been adopted and have improved interoperability between information systems, and this has contributed to a significant increase in data availability. These standards and capacity-building activities to promote their use have helped improve the documentation of *ex situ* collections, facilitating access to PGRFA and improving their management and use.

Today, an array of PGRFA information systems exist across the world, ranging from pen and

[34] The two previous reports on the state of the world's PGRFA (SoW and SoW2) defined genetic erosion as "the loss of individual genes and the loss of particular combinations of genes (i.e. of gene complexes) such as those maintained in locally adapted landraces."

[35] Further information at https://www.cbd.int/gbf/targets/4

Box 5.9

The seven objectives of the International Treaty on Plant Genetic Resources for Food and Agriculture's Global Information System

1. create a web-based platform with use-oriented entry points to plant genetic resources for food and agriculture (PGRFA) information;
2. provide a comprehensive overview and facilitate access to sources of PGRFA and associated information;
3. promote and facilitate interoperability among existing systems by providing clear principles, technical standards and appropriate tools to support the operations in accordance with the principles and rules of the International Treaty;
4. promote transparency on the rights and obligations of users for accessing, sharing and using PGRFA-associated information and to establish ways to exercise those rights and obligations within the Global Information System;
5. create and enhance opportunities for communication and international and multidisciplinary collaboration to increase knowledge about and add value to PGRFA;
6. provide capacity development and technology transfer opportunities for the conservation, management and use of PGRFA and associated information and knowledge, paying special attention to the needs of developing countries; and
7. create a mechanism to assess progress and monitor the effectiveness of the Global Information System.

Source: FAO. 2015. *The vision and the programme of work on the Global Information System.* Resolution 3/2015. Sixth Session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. Rome, Italy, 5–9 October 2015. IT/GB-6/15/Res 3. Rome. https://openknowledge.fao.org/handle/20.500.14283/bl140e

paper collection catalogues to web-based platforms that offer: (i) digital inventory and management systems for genebanks; and (ii) tools that provide interfaces between information systems, whether internal management systems or externally facing platforms for specific users or the public at large. Some of these systems overlap, potentially creating redundancies, while others are converging organically and through structured efforts arising from Article 17 of the International Treaty. This section introduces some of the key international information systems for PGRFA.

The International Treaty's Global Information System on Plant Genetic Resources for Food and Agriculture

Article 17 of the International Treaty foresees the establishment of a global information system that, based on existing information systems, aims to facilitate the exchange of information on scientific, technical and environmental matters related to PGRFA. Work on the development and strengthening of GLIS[36] has continued since the International Treaty entered into force in 2004. In line with its mandate, GLIS provides links to a range of different sources of information.

Increasingly, partnerships and connections have been developed between GLIS and the WIEWS, Genesys, GRIN-Global and EURISCO. Linkages with the CBD's Clearing House Mechanism and SDIS have been strengthened since 2020. Cooperation with the DivSeek International Network, the Global Open Data for Agriculture and Nutrition, the CGIAR Platform and the GBIF has also been strengthened.[37] In addition, easy access to information on seeds and other crop materials for research, training and plant breeding is being provided through the development and promotion of the use of DOIs. The first version of the GLIS Portal went online in 2017, allowing users to share information on their PGRFA holdings and to point to information and knowledge available in referenced databases and systems. DOIs were implemented as central

[36] Further information at https://glis.fao.org/glis

[37] Further information at https://www.fao.org/plant-treaty/areas-of-work/global-information-system/en/

elements of GLIS. In May 2022, a total of 1 228 000 accessions had been identified and linked to related datasets in other systems through the registration of DOIs on the GLIS Portal. By the end of 2021, DOIs had been assigned to 99 percent of accessions conserved by CGIAR genebanks. In addition, DOIs were increasingly referenced in publications and papers. Further efforts focused on automated data exchanges between Genesys and GLIS databases, and the development, implementation and promotion of standards for the documentation of PGRFA (FAO, 2023c). Examples of these include the MCPD, six strategic sets of characterization and evaluation descriptors for multipurpose tropical fruit tree species conserved *in situ*, and a globally agreed list of descriptors for CWR conserved *in situ* (CWRI v.1.1) (Alercia *et al*., 2022).

World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture
WIEWS[38] was established by FAO in 1993 for the preparation of periodic, country-driven global assessments of the status of conservation and use of PGRFA. It collects accession-specific data primarily for the purpose of monitoring national, regional and international *ex situ* germplasm collections over defined periods of time. In addition to accession-level data on *ex situ* collections, it collects and provides detailed information, as well as metadata, on many PGRFA-related matters, including *in situ* conservation and on-farm management, sustainable use, and the building of institutional and human capacities. It currently constitutes the largest source of data for monitoring the status of the global diversity of PGRFA conserved in genebanks. Since the adoption of the GPA2, WIEWS has provided the platform for the monitoring of this instrument. In addition, since December 2016, it serves as the platform for annual reporting on the plant component of SDG Target 2.5, thus acquiring a new role in the implementation of the 2030 Agenda for Sustainable Development. At the time of writing, the passport information of 5.9 million accessions conserved *ex situ* by 852 genebanks in 116 countries and 13 international and 4 regional research centres was available through WIEWS.

Genesys
Genesys,[39] a global web platform that provides information on the crop diversity conserved in national and CGIAR genebanks, has been integrated by GLIS as one of its core services. Genesys publishes the passport, characterization and evaluation data, as well as images, of the accessions conserved in genebanks around the world. It also provides guidance and assistance to genebanks with the documentation of data to make them suitable for publication in line with agreed standards. Since 2013, Genesys has been managed and maintained by the Crop Trust. It continues to evolve as the main PGRFA accession-specific information database. At the end of 2022, it held information from more than 450 genebanks on more than 4 million accessions, which is estimated to represent around half of all accessions conserved worldwide. Ongoing efforts are being made to increase the number of genebanks that feed information into the database.

Germplasm Resources Information Network
GRIN-Global[40] is a freely downloadable data management system originally developed by the United States Department of Agriculture and the Crop Trust to improve standardization among genebanks globally. It enables genebanks to store and manage information associated with germplasm and to deliver that information globally. The first version of GRIN-Global, released at the end of 2011, was replaced by an improved version (version 1.9) in November 2015. GRIN-Global is an extension of the Germplasm Resources Information Network (GRIN) information management system, which was first developed by the USDA's Agriculture Research Service in the mid-1980s. In 2019, work started on the next generation of the system, GG-CE, with the aim of bringing the community of users together

[38] Further information at https://www.fao.org/wiews/en/

[39] Further information at https://www.genesys-pgr.org/

[40] Further information at https://www.grin-global.org/

to improve database usability and functionality. As an open-source tool, GRIN-Global has potential for further development and collective design.

The Global Biodiversity Information Facility
GBIF[41] is an international network and data infrastructure, established by members of the OECD, that is intended to provide open access to data about all types of life on Earth. It provides data-holding institutions around the world with common standards, best practices and open-source tools that enable them to share information about where and when species have been recorded. This information derives from a variety of sources, ranging from museum specimens collected in the eighteenth and nineteenth centuries to DNA barcodes and smartphone photos recorded in recent times. In the context of PGRFA, GBIF contributes in particular to the documentation of CWR and WFP *in situ.*

Implementation of information systems
While progress has been made on improving global information systems, there has been less improvement of national information systems across the world. In 2022, the Secretariat of the International Treaty published a study about bottlenecks and challenges to the implementation of the International Treaty's Article 5 (covering conservation, exploration, collection, characterization, evaluation and documentation) and Article 6 (covering sustainable use) (FAO, 2022b). Difficulties in obtaining information associated with plant genetic materials were identified as an important challenge in all regions, with the specific challenges depending on the type of information concerned. Like the SoW2, the International Treaty study identifies a lack of characterization and evaluation data, especially for minor crops, FV/LR and CWR, as a significant obstacle to the use of PGRFA. The country reporting for the SoW3 indicates that significant gaps in documentation and information sharing on PGRFA still persist in many countries (see 5.7.2; 2.7; 3.13; and 4.10).

Differences also still exist between regions, and between countries within regions, regarding their ability to access, manage and disseminate information. Most countries report not having put in place comprehensive information systems for PGRFA. Moreover, in most regions of the world countries indicate that at the time of reporting much of the existing data were still not electronically accessible, and not all existing digital information systems were publicly available. Where multiple information systems existed, there were no single-entry points to facilitate access to and use of the information stored in them. Time and resources to maintain and update existing databases and keep pace with technological developments were often lacking. Data standardization remained a major challenge, although the progressive adoption of DOIs promised improvement in this area. traditional knowledge on PGRFA was reported to be rarely documented and rarely included in information systems.

With the launch of Genesys in 2011 and the more recent adoption of GRIN-Global and GG-CE, passport data on *ex situ* holdings from the international research centres have been standardized and made accessible over the internet, and to WIEWS for reporting on SDG Indicator 2.5.1.a. Genesys also publishes characterization and evaluation data on a subset of the accessions with passport data.

Ex situ *accession records in information systems*
The increasing number of countries reporting MCPD standardized accession-level data on *ex situ* holdings to WIEWS, either directly or through Genesys and EURISCO, reflects progress at the country level in documenting this information and making it publicly accessible (Figure 5.6). In 2009, no accession-level information was reported by countries, or by international or regional research centres. In 2014, MCPD compliant passport data for 3.6 million accessions from 67 countries and

[41] Further information at https://www.gbif.org/

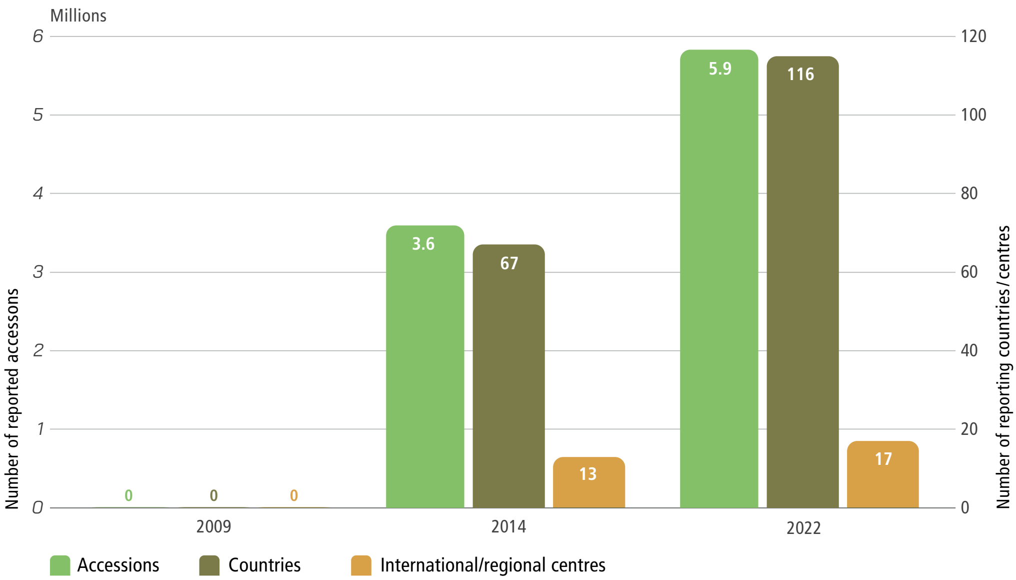
13 international/regional centres were published in WIEWS. By 2022, the numbers had increased to 5.9 million accessions conserved in 116 countries and 17 international/regional centres.

Although progress has been achieved since the SoW2 was published, at the time of reporting for the SoW3 it remained the case that a significant portion of *ex situ* conserved accessions had not been characterized and evaluated for morphological and agronomic traits, and that where such work had been done it had not always been properly documented (see also 4.2). Moreover, existing characterization and evaluation data were frequently not available in publicly accessible databases (see 4.10). About 50 countries out of the 66 reporting on this issue, reported that data on characterization or evaluation of PGRFA *ex situ* collections were made available in public information systems (Figure 5.7). However, the vast majority of the reported information systems proved to be inaccessible when tested during the preparation of this chapter. Countries identify the following issues as major constraints: lack of standardization in data collection, storage and dissemination; lack of capacity development on information systems and data management; and lack of coordination among leading stakeholders.

In situ conservation and documentation of crop wild relatives

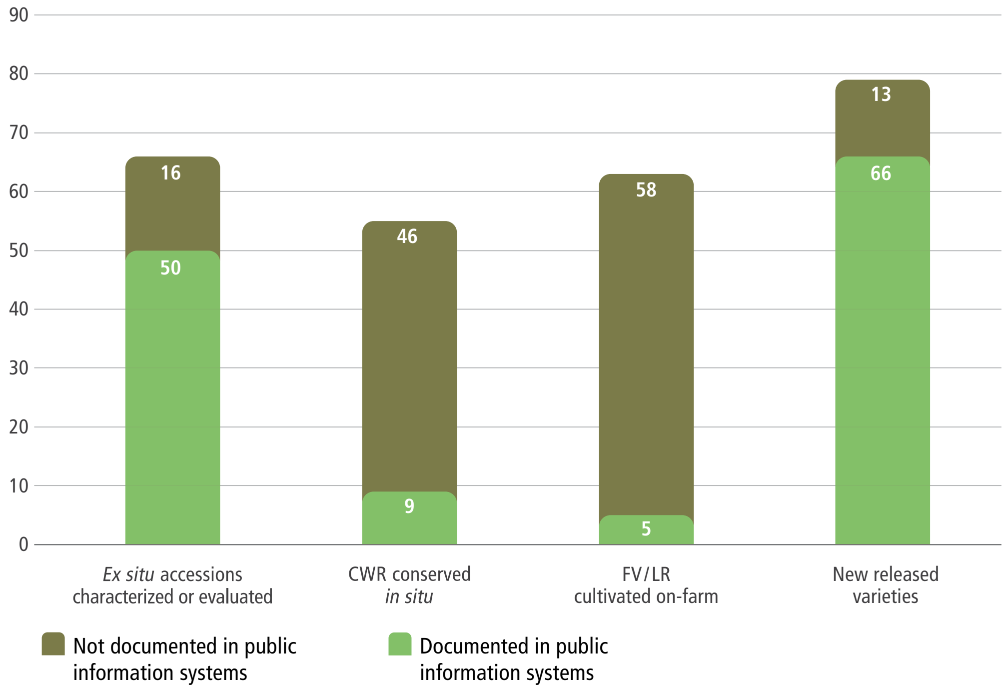
Little progress has been achieved regarding documentation of CWR occurring *in situ*, a category of plants for which systematic *in*

FIGURE 5.6
Accession-level reporting to World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) on *ex situ* holdings, 2009–2022



Sources: FAO. 2017. *Assessment of the implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture 2012–2014*. FAO Commission on Genetic Resources for Food and Agriculture. Rome. https://openknowledge.fao.org/handle/20.500.14283/mr796e; FAO. 2023. *World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)*. [Cited on 19 December 2023]. https://www.fao.org/wiews/en/

FIGURE 5.7
Number of countries documenting different types of plant genetic resources for food and agriculture in public information systems



Notes: CWR = crop wild relatives. FV/LR = farmers' varieties/landraces. Based on reports to four separate questions from a total of 89 countries that reported on this topic.

situ inventories are particularly needed (see 2.7). During the reporting period, work on CWR inventories was often constrained by lack of funding, human resources, knowledge and awareness among stakeholders. CWR conserved *in situ* remained poorly documented in most reporting countries, and consequently there were almost no information systems in place for them. As shown in Figure 5.7, 46 (or 84 percent) of the 55 countries that provided information on this matter indicated that they did not have any CWR populations conserved *in situ* and documented in a publicly available information system. In addition, only one out of the 20 countries that indicated what proportion of their CWR populations had been characterized or included geographic distributions data, also made this information accessible online. The CWR populations published in such cases were also rather few, about 20, or 70 percent, of which were characterized.

On-farm conservation and documentation of farmers' varieties/landraces

As shown in Figure 5.7, 58 out of the 63 countries that reported on the matter did not have any FV/LR, which, while being cultivated on farm, were documented in a publicly available information system. Of the 41 countries reporting that information on FV/LR occurring on-farm was documented, only eight indicated that all these varieties were documented with morphological, agronomic and geographic distribution data and only five published these data through a publicly accessible information system.

Documentation of new varieties released

While 66 countries report having released new varieties and documented them online, 13 countries report not having done so during the reporting period. Fifty-four countries provided further details on the kind of information published for these varieties (Figure 5.8). An agronomic description of the varieties was provided in 84 percent of cases, the source of the seed in 64 percent of cases and pedigree information in 54 percent of cases.

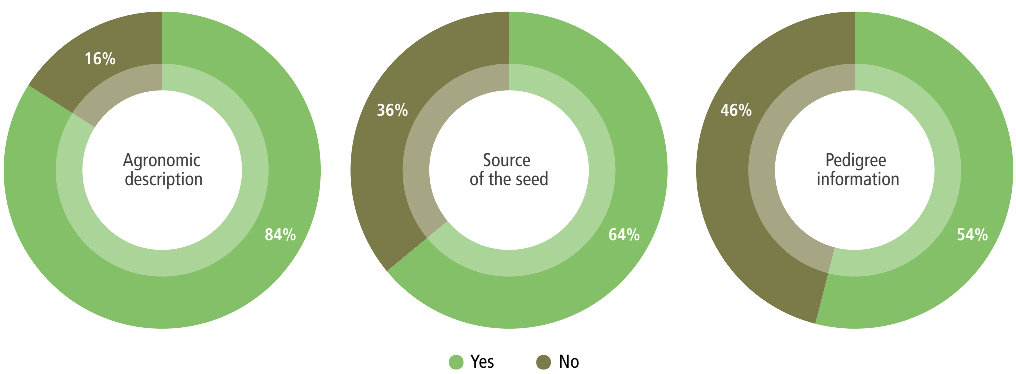
Obtaining and documenting pedigree and other descriptive information on released varieties was reportedly made difficult by constraints such as lack of regulations, lack of public information systems for documenting and describing cultivars, insufficient capacity and technical equipment, poor documentation of the released varieties, and insufficient financial and human resources. Pedigree data were also reported to be generally unknown for the varieties received from the nurseries of CGIAR centres and for materials obtained from other countries. In the case of conventional breeding, pedigree information was often not shared with database managers. Other major constraints mentioned were lack of integration between conservation and utilization programmes (between genebanks and breeding programmes), lack of coordination between relevant stakeholders, and the challenge involved in persuading breeders and scientists to share their pedigree-related data and descriptive information on released varieties.

Contribution of national stakeholders to information systems

Seventy-eight out of 85 countries report that during the reporting period at least one of their national stakeholders contributed to an international information system, such as the ECPGR databases, GBIF (particularly regarding the monitoring/registration of CWR) or smaller

FIGURE 5.8

Percentage of newly released varieties for which different kinds of information were documented, 2012–2019



Notes: Based on 54 country reports.

systems such as the West Indies Sugarcane Breeding and Evaluation Network, although not all the systems were publicly available.

Regional assessment

Northern Africa

Based on the reports of two countries from this region, increased efforts to strengthen national PGRFA documentation and information systems and to export data to international systems were still needed at the end of the reporting period. However, both countries had made progress with the transfer of data from their offline, national information systems into to web-based international information systems, such as Genesys or the Musa Germplasm Information System. Further efforts to improve the national information systems included the provision of training by the Agricultural Plant Genetic Resources Conservation and Research Center of the Sudan to facilitate access to PGRFA-related information through institutional and international platforms.

Sub-Saharan Africa

The main achievements in this region during the reporting period included: computerization of existing information systems in countries such as Eritrea, Ethiopia, Ghana, Guinea, Namibia, Nigeria, South Africa and Zambia; documentation of an increased number of registered varieties (e.g. Kenya); installation of database management systems, such as GRIN-Global or the Botanical Research And Herbarium Management System (BRAHMS[42] or use of Genesys or GBIF (e.g. in Ghana, Kenya and Nigeria); publication of accession-level information via WIEWS on an annual basis; employment of more staff to support information systems (e.g. Nigeria); and training of relevant staff (e.g. South Africa). However, none of the 18 reporting countries report having a comprehensive information system in place for PGRFA.

No country reports having had an information system in place for CWR or for FV/LR conserved *in situ*. In general, the information stored was not publicly available. The capacities of stakeholders regarding PGRFA information systems and data management also needed further strengthening. Several country reports note the importance of better coordinating and better financing PGRFA-related information management and of ensuring reliable access to the internet.

Northern America

The implementation of a customized version of GRIN-Global, efforts to analyse genetic sequence data and upload them to public databases and the development of DNA libraries associated with molecular catalogues for PGRFA collections were among Canada's main achievements during the reporting period. The country identifies no major gaps and needs. However, it notes the major importance of improving the availability of the genetic sequence data and other molecular information related to accessions generated by the PGRFA users. It also notes the standardization of data from "-omics" disciplines as an emerging issue.

Latin America and the Caribbean

As in the other regions, the information systems that existed in Latin America and the Caribbean during the reporting period focused mainly on PGRFA conserved *ex situ*. The amount of progress made varied from country to country. Existing systems ranged from very basic documentation in spreadsheet tables to very advanced systems, such as GRIN-Global. Several country reports (e.g. Brazil, Colombia and Peru) identify the computerization, development or updating of information systems to make PGRFA related information publicly available as priorities. The standardization of information systems, building capacity to use them and providing them with adequate financial support are also identified as essential, as is strengthening the documentation and monitoring of CRW and FV/LR conserved *in situ*, as this is a precondition for their inclusion in information systems.

[42] Further information at https://herbaria.plants.ox.ac.uk/bol/

Asia
The progress made in this region during the reporting period varied greatly by country. Major achievements since the publication of the SoW2 included: the digitalization of the existing information systems in countries such as Malaysia and Yemen; the further inclusion of characterization and evaluation data in databases in Azerbaijan; the increased use of modern technologies for PGRFA management by scientists, researchers, curators and genebank managers in Indonesia; the development of web-based and mobile applications to facilitate access to PGRFA-related information in India; the development of databases for CWR and WFP in Nepal; and the increased contribution to regional and international information systems such as GRIN Global (e.g. in Jordan) or EURISCO (e.g. in Armenia and Azerbaijan).

Despite this progress, the need to further strengthen existing systems and to develop information systems for CWR and FV/LR conserved *in situ* is recognized in the reports from several of the region's countries. Financial resources, capacity building on the management of information systems, improved cooperation between stakeholders, and standardization of data and of characterization and evaluation activities are also identified as major needs.

Europe
In general, most countries had information systems for *ex situ* conservation holdings in place during the reporting period. In all but three of the 20 reporting countries, the information was publicly available. However, at the time of reporting, two countries still did not have electronic databases. Key achievements in the region during the reporting period included the development of an updated information system (GRIN Czech) in Czechia for the documentation of PGRFA conserved *ex situ*, *in situ* and on farm, the update of the national inventory of PGRFA in Germany, where the database structure was improved and descriptors for *in situ* and on-farm data were developed, and the establishment of a yearly national reporting procedure in Norway, which allows for the assessment of the status and trends of genetic resources for food and agriculture (animal, forest and plant). The Nordic Baltic Genebanks Information System is described in Box 5.10. Online sources of CWR-related information in the Kingdom of the Netherlands are described in Box 5.11.

The transfer of information to EURISCO was widespread in the region. Countries' membership of ECPGR helped to standardize the documentation and conservation practices of their genebanks. The ECPGR crop-specific databases provided data about the conservation, characterization and use of accessions of specific crops. Most of these databases, however, were not regularly updated.

While websites and web pages dedicated to CWR had increasingly been developed, there remained significant gaps regarding the development of information systems for CWR conserved *in situ*. Even greater gaps remained with respect to the documentation and creation of information systems for FV/LR. Developing such systems remained a major challenge. As

Box 5.10
Nordic Baltic Genebanks Information System

The Nordic Baltic Genebanks Information System (GeNBIS), a database tool that gathers information on the plant genetic resources held in the genebanks of the Nordic and Baltic countries (Denmark, Finland, Iceland, Norway, Sweden, Estonia, Latvia and Lithuania), was established in 2020 to replace the former SESTO database system. This represents a major step towards harmonizing the documentation of genebank accessions in the region as well as globally, using the Germplasm Resources Information Network – Global (GRIN-Global).

Source: GeNBIS. 2024. About Nordic Baltic Genebanks. [Cited 18 December 2024]. https://www.nordic-baltic-genebanks.org/gringlobal/about

Box 5.11

Online sources of information on crop wild relatives in the Kingdom of the Netherlands

The CWRnl website,[a] which was established in 2014, makes information on 214 taxa available through fact sheets containing data on the genetic and biological similarity between crop species, their conservation status and distribution. For the 53 crop wild relatives (CWR) included in the Dutch Red List of Threatened Species, CWRnl presents expected distribution maps for the year 2070 based on climate change scenarios. It also presents information on the occurrence of these CWR in protected nature reserves and on the samples of their seeds in genebanks.

The Orange List[b] contains around 6600 agricultural and horticultural varieties (of 63 crops) that were grown from 1850 until the Second World War in the Kingdom of the Netherlands. Since August 2019, Dutch heritage varieties have been earmarked on the Orange List, which provides information on where varieties are still commercially available and/or in which genebank they are conserved. About 900 of the varieties included are still commercially available and about 1 000 are being conserved in genebanks.

[a] Further information at https://www.cwrnl.nl/en/cwrnl-1.htm

[b] Further information at https://deoerakker.cgn.wur.nl/oranjelijst.htm

in the other regions, this implies the need to strengthen efforts to document and monitor their occurrence. Improving coordination between stakeholders as well as data standardization also remained key challenges.

Oceania

The only reporting country from this region did not report any achievements in this field. It highlighted the need to develop a comprehensive information system, make information on PGRFA publicly available and export such information to global information systems.

5.5.2 Systems for monitoring and safeguarding genetic diversity and minimizing genetic erosion

Loss of crop diversity has been discussed for more than a century. At the time of publication of the SoW2, the development of new molecular techniques had already led to an increase in the amount of data available on genetic diversity, which in turn allowed issues such as domestication, genetic erosion and genetic vulnerability to be better understood. The SoW2 noted that despite growing public awareness of the importance of PGRFA, many country reports expressed concern about the extent of genetic vulnerability and the need for greater deployment of genetic diversity. Along the same lines, a 2022 study that analysed scientific papers on PGRFA genetic erosion published between 1939 and 2021 found that more than 95 percent of the publications reviewed reported changes in diversity and that almost 80 percent found evidence of genetic loss (Khoury *et al*., 2022). However, the magnitude and trends of genetic erosion are not yet sufficiently understood, and this constitutes a major constraint to the design of effective conservation measures (Khoury *et al*., 2022). This lack of knowledge and standard methodologies have constrained the establishment of baselines, which are needed in order to assess trends and hence to identify conservation priorities (Thormann and Engels, 2015).

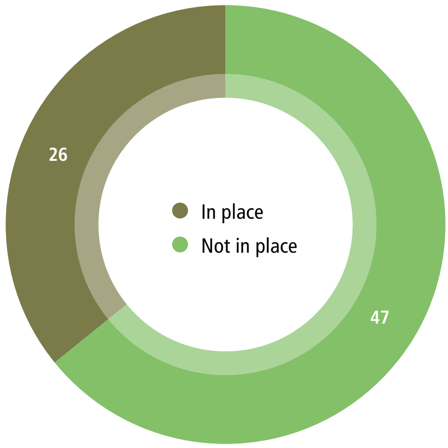
Traditionally, efforts to understand and mitigate genetic erosion focused mainly on surveying and inventorying PGRFA *in situ* and on farm, collecting them and conserving them in *ex situ* facilities. Since the publication of the SoW2, recognition of the benefits of combining *ex situ* and *in situ* conservation efforts have further increased, as has awareness of the need to monitor genetic status and trends of PGRFA diversity to inform policy decisions and PGRFA management.

At the end of 2019, almost two-thirds of the reporting countries (47 of 73, or 64 percent)

(Figure 5.9) had some sort of national system or mechanism in place for monitoring and safeguarding genetic diversity and minimizing genetic erosion. National genebanks, with their *ex situ* collections and established protocols for monitoring sample viability and regenerating samples when inventory or viability are low, were reportedly key players in these mechanisms. Protected areas and their management also played an important role in safeguarding genetic diversity and minimizing genetic erosion as part of these national systems or mechanisms. The overall expansion of protected areas observed in most countries has therefore also contributed to the conservation of CWR and WFP *in situ*, although most of these protected areas lack specific management plans for these important plant groups.

Some initiatives related to the development of biodiversity indicators, including for indicators related to PGRFA, are described in Box 5.12.

FIGURE 5.9
Number of countries with systems in place for monitoring and safeguarding plant genetic diversity as of 2019



Source: Based on 73 country reports.

Box 5.12
France's Agroforestry Development Plan, 2015–2020

Several international organizations are working to develop indicators to enable comparison of the current, recent and future status of biodiversity at the genetic, species and ecosystem levels. Some of these indicators have been internationally agreed, such as the those used for measuring progress towards the Sustainable Development Goals (SDGs) and those developed for the Commission on Genetic Resources for Food and Agriculture, the Convention on Biological Diversity (CBD) or the International Union for Conservation of Nature (IUCN).

The Biodiversity Indicators Partnership,[a] which brings together 60 organizations, has been working since 2007 to promote and coordinate the development and delivery of biodiversity indicators developed for use by the CBD, other biodiversity-related conventions, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and national and regional agencies, including for monitoring progress towards the SDGs.

The IUCN Red List of Threatened Species is set to increase in importance as a tool for measuring progress towards the reduction of genetic erosion of crop wild relatives and wild food plants.

Although not internationally agreed, the Alliance of Bioversity International and CIAT developed an Agrobiodiversity Index[b] that assists in measuring genetic diversity *in situ* and *ex situ*, and in markets and in people's diets.

The Group on Earth Observations Biodiversity Observation Network (GEO BON) developed the metric Essential Biodiversity Variables to help aggregate, harmonize, and interpret biodiversity observation data from diverse sources (Hoban *et al.*, 2022).

Source: Hoban, S., Archer, F.I., Bertola, L.D., Bragg, J.G., Breed, M.F., Bruford, M.W. *et al*. 2022. Global genetic diversity status and trends: towards a suite of Essential Biodiversity Variables (EBVs) for genetic composition. *Biological Reviews*, 97(4), 1511–1538.

[a] Further information at https://www.bipindicators.net/about
[b] Further information at https://www.agrobiodiversityindex.org

Tools for monitoring and assessing genetic diversity using molecular data are now available. For example, molecular markers are used to assess diversity and genetic erosion in *ex situ* collections and for analysis of the genome-wide genotyping of genebank accessions. However, these technologies are still not always affordable and easy to use and, therefore, their use is not widespread (Wambugu, Ndjiondjop and Henry, 2018).

Overall, progress in safeguarding the genetic diversity of plants and their wild relatives since the publication of the SoW2 has been insufficient. The country reports show that to varying degrees countries did monitor the state of conservation of their PGRFA conserved *ex situ* and to a lesser extent *in situ*. However, these activities were often just part of individual research projects, surveys conducted by individual researchers or efforts by NGOs, education or research institutions to monitor the crops being grown in farmers' fields, i.e. did not form part of wider, more comprehensive programmes.

Other initiatives that helped promote monitoring efforts included the development of relevant laws and national strategies and action plans, the operation of specific monitoring programmes, the establishment of relevant government departments or working groups, improvement and standardization of the conservation procedures used by genebanks, and the development of catalogues and scientific publications. However, the country reports indicate that the GPA2 objective of monitoring effectively genetic diversity and minimizing genetic erosion remained far from having been achieved. Greater effort to document the patterns of PGRFA diversity is therefore needed, including an effort to ensure greater participation of the relevant local actors, including smallholder and peasant farmers Indigenous Peoples and local communities.

Regional assessment

Northern Africa

An example of the achievements made in the region during the reporting period was the development in Tunisia (the only country in the region that provided information on this topic) of the national register of wild species (REGNES),[43] which constituted a first nucleus of a Tunisian red list. However, the country did not have a specific system in place for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Limited financial and human resources were identified as major constraints.

Sub-Saharan Africa

As during the reporting period for the SoW2, no systematic monitoring of genetic diversity was undertaken in the region during the reporting period for the SoW3. However, a number of achievements are noted in the country reports, including the organization of more (and more targeted) collecting missions (Botswana, Ethiopia, Kenya), more and better documentation, characterization and monitoring of *ex situ* collections (Botswana, Ethiopia), the development of biodiversity registers for genebanks (Mali), and the creation of safety duplicates of newly released varieties and the shipment of the duplicates to the SGSV (Nigeria).

New CSBs were established, existing ones were strengthened (Ethiopia, Mali) and local communities were trained in CSB management (Zambia). Seed fairs were organized in countries such as Ethiopia, Kenya, Mali and Zambia. In Mali awareness of the risks of genetic erosion was improved through radio and television broadcasts in local languages.

The need to monitor and safeguard genetic diversity and minimize genetic erosion was included in the draft PGRFA policy and the PGRFA National Strategy of Uganda. However, while awareness of the importance of CWR and WFP generally increased in the region, little collection or characterization work on these species appears to have been done. Major constraints to establishing a formal monitoring system for PGRFA and to implementing comprehensive country-

[43] Further information at https://environnement.gov.tn/tunisie-environnement/la-diversite-biologique/conservation-de-la-nature

wide PGRFA surveys in the region included a lack of financial resources, a lack of coordination among stakeholders, a lack of comprehensive and harmonized policy and legal frameworks for PGRFA conservation and use, limited capacities and staff shortages.

Northern America

In Canada, tools for monitoring and assessing genetic diversity evolved during the reporting period from those associated with classical taxonomy and agribotanical characterization to those associated with molecular assessments. The management of diverse genebank collections with considerable inter- and intra-accession diversity remained a challenge and there was reportedly a need to be strategic when making new material acquisition decisions.

Latin America and the Caribbean

Overall, reporting countries did not have national systems in place during the reporting period for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Countries, however, report several achievements. For example, in Chile, increased selection, domestication and improvement of CWR and FV/LR led to an increase in their use and value. In Cuba, commitment to annual monitoring for SDG Indicator 2 and to submit information to WIEWS incentivized centres involved in *ex situ* conservation of PGRFA to better monitor the status and viability of their collections.

Most reporting countries recognize the need to develop a national monitoring system for PGRFA, as well as the urgency of conducting comprehensive country-wide PGRFA surveys, particularly regarding CWR. Weak PGRFA coordination structure and a lack of indicators for identifying genetic vulnerability in order to develop early warning systems are identified as major constraints.

Asia

None of the 17 reporting countries from Asia had a system in place during the reporting period for monitoring and safeguarding PGRFA and their wild relatives or for minimizing genetic erosion. However, countries report some progress. For example, a national system to monitor and protect PGRFA diversity and their wild relatives was developed in Azerbaijan, where improvements were also made to storage conditions in *ex situ* collections. In Myanmar, safety duplicates were sent to other genebanks. In Indonesia, genebanks were established at the local and national levels and crop breeding programmes were strengthened. Exchange of PGRFA with international/regional partners and/or genebanks to increase crop diversity occurred in countries such as Indonesia and Kyrgyzstan. Awareness of the importance of genetic diversity was raised among farmers and local communities during collecting missions in Malaysia and Myanmar. In Nepal, baseline reports were developed for monitoring the status of landraces on farm. Similarly, in Türkiye, national inventory studies on landraces, CWR and other wild plants were conducted.

In situ monitoring and *ex situ* storage of CWR and WFP generally remained limited in the region as did their inclusion in information systems. However, some countries report significant progress, including establishing national parks (Azerbaijan), increasing the collection and conservation of CWR and WFP and increasing their availability for use of by farmers and in breeding programmes (Lebanon), developing projects and activities focused on *in situ* conservation and sustainable harvesting, and developing the use, domestication and cultivation of edible and aromatic WFP (Lebanon).

Major gaps in the region included shortages of financial resources and the absence of comprehensive country-wide PGRFA surveys, indicators for PGRFA monitoring and early warning systems. The lack of national breeding programmes that made use of CWR, WFP or FV/LR and the absence of national regulations encouraging their use were particular constraints. Where such provisions were in place, they were inadequately implemented.

Europe

Two out of the 16 reporting countries report having had national systems in place during the reporting period for monitoring and safeguarding genetic diversity, yet both report difficulties in implementing them effectively because of a lack of coordination of activities at the national level, limited exchange of information between relevant institutions, lack of data standardization and insufficient monitoring. A CWR-related initiative in Germany is described in Box 5.13.

Progress reported from the region included improved reporting of field collections (Norway), strengthened capacity for long-term storage in *ex situ* collections (Poland), improved coordination and information sharing between stakeholders, and publication of catalogues and/or inventories of FV/LR and/or of accessions conserved *ex situ* (Switzerland). However, major needs remained, particularly the need to strengthen monitoring efforts and to conduct country-wide PGRFA surveys. Insufficient financial resources were a constraint. The extension of EURISCO to cover CWR-related data is described in Box 5.14.

Oceania

The only reporting country in this region provided no information on achievements or changes in this field. The major constraint identified was the lack of a national policy and strategic framework for coordinating the conservation, management and use of PGRFA across sectors, organizations and government agencies.

5.6 Multilateral access to plant genetic resources, the sharing of benefits arising from their utilization and the realization of Farmers' Rights

Access to germplasm for conservation and sustainable use is fundamental to the effective implementation of the GPA2. However, for reasons of justice and equity, such access also

Box 5.13

The German Network of Genetic Reserves

Established in 2019 under the Federal Office for Agriculture and Food, the German Network of Genetic Reserves coordinates existing and planned *in situ* conservation measures for crop wild relatives (CWR). It consists of subnetworks for priority CWR, such as wild celery, wild grapevine and Arnica, which are coordinated by specialist agencies. The network facilitates regular and targeted monitoring of CWR.

Source: Federal Office for Agriculture and Food. 2024. *German Network of Genetic Reserves*. [Cited 15 April 2024] https://www.genres.de/en/sector-specific-portals/cultivated-and-wild-plants/in-situ-conservation-of-cwr/german-network-of-genetic-reserves#:~:text=The%20German%20Network%20of%20Genetic,in%20their%20areas%20of%20distribution

Box 5.14

The European Search Catalogue for Plant Genetic Resources for crop wild relatives

In 2023, the European Search Catalogue for Plant Genetic Resources (EURISCO) was extended to include data on *in situ* crop wild relatives (CWR) within the framework of the European Cooperative Programme for Plant Genetic Resources (ECPGR) with the support of a German-funded project. "Descriptors for uploading *in situ* CWR passport data to EURISCO"[a] based on the Descriptors for Crop Wild Relatives (CWRI v.1.1) published by Alercia *et al.* (2022) were developed and adopted. The implementation of these data-exchange standards and a standard procedure for uploading CWR to EURISCO helped to harmonize and systematize CWR monitoring and to improve the sharing of information on CWR in the region.

Source: Alercia, A., López, F., Marsella, M. & Cerutti, A.L. 2022. *Descriptors for Crop Wild Relatives conserved in situ (CWRI v.1.1). Revised version.* Rome, FAO on behalf of the International Treaty on Plant Genetic Resources for Food and Agriculture. https://doi.org/10.4060/cb3256en

[a] Further information at https://eurisco.ipk-gatersleben.de/apex/eurisco_ws/r/eurisco/eurisco-documents

needs to lead to sharing benefits arising from the use of the germplasm.

The International Treaty remains the central international instrument governing the conservation and sustainable use of PGRFA as well as ABS in this context. As of July 2024, the International Treaty had 152 Contracting Parties, including the European Union, up from 127 in 2011, when the SoW2 was published. Of particular note in this context are the ratifications by Argentina, Japan and the United States, all of which have important PGRFA collections. However, Contracting Parties are still unevenly distributed across the regions.

The International Treaty not only promotes and facilitates the conservation and sustainable use of PGRFA (Articles 5 and 6), it also recognizes the "enormous contribution" of farmers to the diversity of the crops that feed the world (Article 9). It establishes a global system that provides facilitated access to plant genetic materials and simultaneously ensures that recipients share the benefits they derive from the use of these materials (Articles 10–13). The International Treaty's Funding Strategy (Article 18) is described in Section 5.3.4.

The International Treaty and the GPA2 are closely interrelated and mutually reinforcing. Article 14 of the International Treaty recognizes the importance of the rolling GPA and calls upon Contracting Parties to "promote its effective implementation". Furthermore, Article 17.3 of the International Treaty provides that "Contracting Parties shall cooperate with the Commission on Genetic Resources for Food and Agriculture of the FAO in its periodic reassessment of the state of the world's PGRFA in order to facilitate the updating of the rolling GPA". In its turn, the GPA2 is an important mechanism for the effective implementation of the International Treaty's objectives.[44]

[44] As of October 2024, 179 countries and the European Union were members of the Commission; 145 of these were also Contracting Parties of the International Treaty.

This section focuses on two aspects of pivotal relevance to the achievement of the objectives of the GPA2 – the MLS and Farmers' Rights – from the point of view of human and institutional capacities.

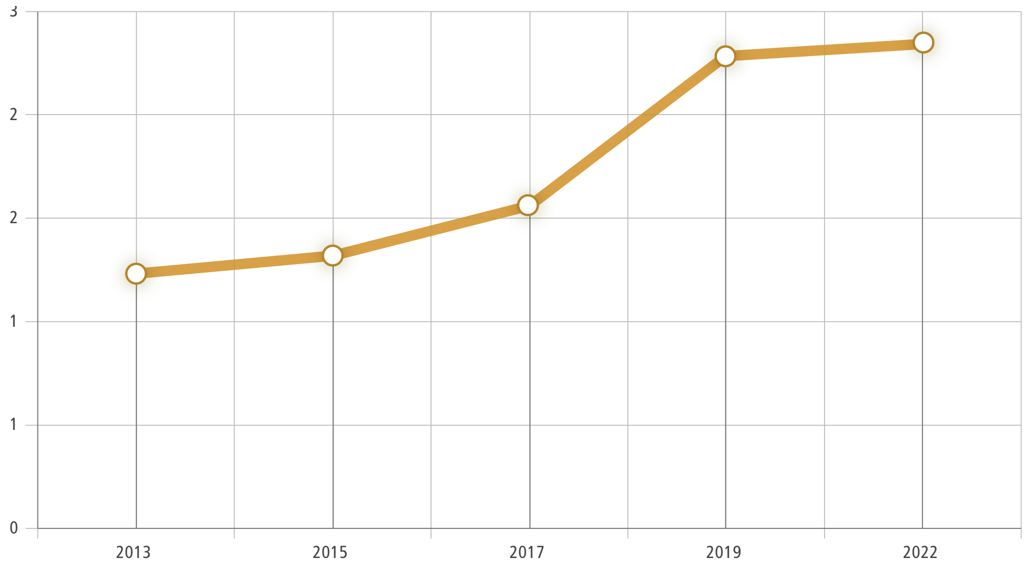
5.6.1 Access and benefit-sharing

Although the International Treaty applies to all PGRFA, its MLS, a special regime of facilitated access, currently applies to the 35 food crops and 29 forages listed in its Annex 1 that are under the management and control of the Contracting Parties of the International Treaty and in the public domain. The MLS treats the materials listed in Annex 1 as part of a common pool shared by Contracting Parties and the entities under their jurisdiction, and it makes these available without any condition on access other than those included in the SMTA. The MLS and the SMTA facilitate the exchange of the genetic resources of these crops without the need for complex bilateral negotiations, as is currently still the case under the CBD's Nagoya Protocol (see Section 5.3.2). It also provides for the sharing of benefits from the use of these common pool resources, including via the International Treaty's Benefit-sharing Fund, not least as a form of compensation for the intergenerational work of farmers in creating crop diversity (Girard and Frison, eds, 2018; Halewood and Nnadozie, 2008; Moeller, 2021).

Facilitated access to ex situ *collections*

The MLS and the facilitated access to crop germplasm that it provides are understood by the International Treaty as a benefit in themselves that is shared between all Contracting Parties, user organizations under their jurisdiction and beyond. Since the International Treaty came into force in 2004, and increasingly since the publication of the SoW2, more and more non-Annex 1 accessions have been released under SMTAs. Several Contracting Parties to the International Treaty have, as an independent policy decision, issued non-Annex 1 accessions in their holdings under SMTAs. More than 2.3 million materials, comprising accessions held by national collections

FIGURE 5.10
Number of accessions available in the Multilateral System, 2013–2022



Sources: FAO. 2013. *Report on the implementation of the Multilateral System of Access and Benefit Sharing*. Fifth Session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. Muscat, Oman, 24-28 September 2013. IT/GB-5/13/5. Rome. https://openknowledge.fao.org/handle/20.500.14283/be561e; FAO. 2017. *Report on the availability of material in the Multilateral System*. Seventh Session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. Kigali, Rwanda, 30 October – 3 November 2017. IT/GB-7/17/Inf.4. Rome. https://openknowledge.fao.org/handle/20.500.14283/bs796e; FAO. 2019. *Report on the implementation and operations of the Multilateral System*. Eighth Session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. Rome, 11–16 November 2019. IT/GB-8/19/8.1 Rev.1. Rome. https://openknowledge.fao.org/handle/20.500.14283/na911en; FAO. 2022. *Report on implementation and operations of the Multilateral System*. Ninth Session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. New Delhi, India, 19–24 September 2022. IT/GB-9/22/9.1. Rome. https://openknowledge.fao.org/handle/20.500.14283/ni825en

(1.4 million), CGIAR collections (805 124) and other collections (55 922) are available for distribution under the terms and conditions of the SMTA (FAO, 2023c), implying that access has overall been enhanced since the publication of SoW2. In 2017, the United States decided to add approximately 500 000 accessions into the MLS, making them available under an SMTA, significantly increasing the pool of shared germplasm. The development of the SMTA generation and reporting mechanism EasySMTA[45] has also facilitated access since the publication of the SoW2.

As shown in Figure 5.10, the MLS has grown significantly since publication of the SoW2. The reduced rate of growth during 2020–2022 is likely to have been caused, inter alia, by disruptions associated with the COVID-19 pandemic. In some countries, pandemic restrictions also complicated the distribution of germplasm from genebanks during this period.

Despite the overall progress in the amount of germplasm available under the MLS, the lack of availability of Annex 1 material held by several Contracting Parties to the International Treaty still hampers the full functioning of the system.

45 Further information at https://mls.planttreaty.org/itt/index.php

Germplasm exchange

Information on germplasm movement is a good indicator of the extent to which PGRFA are being used and exchanged globally and, therefore, can be used to evaluate how access to PGRFA is being promoted and facilitated. Germplasm movement involves exchange between genebanks, acquisitions by genebanks from research and breeding programmes, and distributions to plant breeders, researchers and farmers.

According to the Secretariat of the International Treaty (FAO, 2023c), there was a steady increase in the total number of SMTAs reported over the period from 2007 to 2020. As of mid-June 2022, the total quantity of MLS materials transferred since 2007 was 6 396 485, under a total of 90 688 SMTAs (FAO, 2023c). Eleven percent of these materials were distributed by the International Treaty's Contracting Parties, 89 percent by Article 15 institutions (CGIAR centres) and almost 25 500 by providers in countries that are not Contracting Parties. These figures indicate the extent to which users are accessing, and thereby benefiting from, PGRFA for research, breeding and training. For more information, see Chapter 3 and the thematic background study on germplasm exchange (Khoury *et al.,* forthcoming).

National access and benefit-sharing legislation

Based on data reporting under SDG Target 15.6[46] (UNSD, 2022), 39 countries have implemented ABS measures that fulfil the requirements of both the Nagoya Protocol and the International Treaty either through integrated frameworks or distinct but complementary approaches. However, these data do not provide evidence as to whether the measures had any impact. New indicators for ABS have been adopted in the context of the Kunming-Montreal Global Biodiversity Framework, which provides the opportunity to improve monitoring and evaluation of ABS activities and enhance the mutually supportive implementation of the two ABS instruments.[47]

Some countries report that the COVID-19 pandemic led to delays in legislative processes and in the implementation of other ABS-related activities, and this could have contributed to delays in progress towards SDG Target 15.6 in these countries (UNSD, 2022).

Countries have chosen different paths to implement the International Treaty and the MLS. Some countries have adopted or amended relevant legislation in recent years (Box 5.15). Other countries were able to implement the International Treaty and the MLS through administrative and or procedural changes that did not require amendments of existing or the adoption of new laws (FAO, 2021a).

Box 5.15

Examples of adopted national legislation of relevance to the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture

Legal measures related to the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture (International Treaty) include:

- Spain's Decree 429/2020 of 3 March 2020, which regulates access to plant genetic resources for food and agriculture and cultivated plants taking into account the provisions of both the International Treaty and the Nagoya Protocol;
- an implementation strategy and action plan for the implementation of the International Treaty and its Multilateral System between 2015–2020 in Nepal; and
- a dedicated law to support implementation of the International Treaty in Lebanon, and concomitant establishment of a National Plant Genetic Resources Committee under the Ministry of Agriculture (Decision 394, 12/05/2014).

[46] Target 15.6: Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed. Indicator 15.6.1: Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits.

[47] Further information at https://www.cbd.int/abs/gbf.shtml#tab=5

Monetary benefit-sharing

Under certain conditions of use – particularly if MLS materials form part of the parentage of a commercial plant variety– monetary benefit-sharing obligations are triggered through the provisions of the SMTA. However, as long as the commercial plant variety remains available for further research and breeding (e.g. when its intellectual property protection allows for a breeders' exemption), monetary benefit sharing remains voluntary. Since its inception, the Benefit-sharing Fund of the International Treaty has only received a few mandatory benefit-sharing payments. These totalled less than USD 400 000 as of February 2023. While it needs to be highlighted that all the payments were made after the publication of the SoW2, the great majority of all finance flowing into the Benefit-sharing Fund consists of voluntary contributions from Contracting Parties, international institutions and the private sector. This is particularly significant given that it is estimated that more than 1 000 material transfers occur daily via SMTAs (FAO, 2019). As of November 2022, 67 projects had been funded with the resources from the Benefit-sharing Fund over a total of four project cycles. The sums involved amounted to approximately USD 30 million (mostly, as noted above, coming from voluntary contributions, and including more than USD 1 million provided by the private sector).

Given the above figures, the compensatory function of the MLS – its monetary benefit-sharing provisions – has increasingly been called into question since the publication of SoW2 (Frison, Lopez and Esquinas-Alcazar, eds, 2011; Girard and Frison, eds, 2018; Moeller and Stannard, 2013; Wynberg *et al.*, 2021).

A process aimed at improving the functioning of the MLS was established under the International Treaty in 2013. The working group tasked with developing proposals that could contribute to this objective discussed various measures before its suspension in 2019. These measures included the expansion of Annex 1 so as to include more, or even all, PGRFA in the MLS, and the revision of the SMTA to create a de facto subscription system and make all benefit-sharing payments mandatory. Because of a number of disagreements, including on the question of whether the use of DSI associated with MLS material should also trigger benefit-sharing obligations, no decisions on changes to the MLS had been taken at the time of writing. However, with negotiations having been relaunched at the Ninth Session of the International Treaty's Governing Body in September 2022, renewed progress on the enhancement of the MLS is possible.

Aside from providing for monetary benefit-sharing, the International Treaty also urges the recipients of material from the MLS to share non-monetary benefits resulting from research and development carried out on the material through "the exchange of information, access to and transfer of technology, [and] capacity-building" (Article 13.2).

Digital sequence information

Since the publication of the SoW2, the significance of DSI (Box 5.16) in the plant sciences and associated technologies, and specifically in plant breeding, has increased exponentially.

Box 5.16
Digital sequence information

Digital sequence information (DSI) is an umbrella term that refers to digital information on genetic resources, for example genetic sequence data. Deoxyribonucleic acid (DNA) sequences, Ribonucleic acid (RNA) sequences and protein sequences as well as metadata, annotations and related information, can all fall under the term DSI, and all are held in databases around the world from which they can be downloaded. As its precise meaning and scope are still being debated, the term "DSI" is currently used as a placeholder until agreement is reached.

Source: DSI Scientific Network. 2024. *DSI Scientific Network*. [Cited 18 June 2024]. https://www.dsiscientificnetwork.org/

The implications of DSI have been raised in the context of the International Treaty, the Commission, the CBD and its Nagoya Protocol, and other fora (CBD, 2018). Positions diverge, sometimes sharply, on whether and how DSI should be addressed under these agreements. The main concern regarding DSI is that it represents information that is often publicly available online and that, because of technological advances, may substitute for the use of the physical, biological material to which it relates. The concern is that certain research and development activities can be conducted, and commercially exploited, purely by accessing and processing DSI, thereby circumventing the need to access the physical material. Depending on the scope of ABS measures, circumventing material access to genetic resources could then allow the requirements of ABS measures to be circumvented, including benefit-sharing obligations.

While DSI is playing increasingly important roles in taxonomy, and thereby conservation management, and in tracking threatened species and preventing illegal trade, it is of particular relevance to genetic engineering and molecular recombination technologies (Smith, Ryan and Buddie, 2023). Given the economic value of these technologies, DSI potentially catalyses enormous monetary benefits for organizations with the capacity to exploit them. However, the societal and environmental benefits created by them are controversial.

Millions of genetic data sequences are submitted to open-access databases every year and can easily be shared and replicated. Therein lies the value of DSI, which is accrued through processing high volumes of digital data by multiple users in multiple iterations. Tracing its origin, uses and transformations along value chains is complex if not impossible. Since the absence of specific provisions relating to the use of DSI in the International Treaty or the CBD could lead to a loss of monetary and non-monetary benefit-sharing potential in a world in which genetic information plays an increasingly pivotal economic role, the Kunming-Montreal Global Biodiversity Framework, under its Target13, clarifies the need to ensure the sharing of benefits that arise from the utilization of genetic resources and from DSI on genetic resources.

There are also fears that new benefit sharing mechanisms may hinder crop research. Since such data are commonly available via open-access platforms, many crop researchers take unhindered access to them for granted and have built their work on the premise of accessibility. It has been suggested that systems of exchange that are, if not fully open, then at least multilateral might allow the important benefits of DSI for scientists and managers of genetic resources to be retained (FAO, 2022c; Brink and van Hintum, 2021; Cowell *et al*., 2021). Crucially, the capacity to make use of and benefit from the growing and complicated datasets that are now available varies significantly across institutions, countries and regions. Capacity building is critical if the benefits of DSI are to be the widely and equitably enjoyed (FAO, 2022c; Cowell *et al*., 2021; Rohden *et al*., 2020; De Jonge, Salazar and Visser, 2021).

In December 2022, the Conference of the Parties (COP) to the CBD agreed that "the benefits from the use of digital sequence information on genetic resources should be shared fairly and equitably" and decided "to establish, as part of the Kunming-Montreal Global Biodiversity Framework, a multilateral mechanism for benefit-sharing from the use of digital sequence information on genetic resources, including a global fund" (CBD, 2022b). At its sixteenth meeting in October 2024, the COP adopted the modalities for operationalizing the multilateral mechanism, including a global fund:

The multilateral mechanism covers DSI on genetic resources:

a) "that is made publicly available, in compliance with national legislation, where applicable;
b) that is not subject to mutually agreed terms established at the time of access to the genetic resources from which the DSI on genetic resources is derived, unless those terms allow for the making of the DSI freely available; and
c) for which the fair and equitable sharing of benefits on the use of DSI on genetic resources

> is not provided for by other international agreements on access and benefit sharing, except if those instruments choose the multilateral mechanism for that purpose" (CBD, 2024).

According to the decision, users of DSI on genetic resources in sectors that directly or indirectly benefit from its use in their commercial activities (such as pharmaceuticals, nutraceuticals, cosmetics, animal and plant breeding, and biotechnology) should contribute a proportion of their profits or revenue to the global fund, named the Cali Fund, according to their size.

While all users of DSI should share benefits, larger entities of a certain size benefiting commercially from using DSI should contribute 1 percent of their profits or 0.1 percent of their revenues as an indicative rate. The mechanism targets larger companies most reliant on DSI. Public databases, academic and public research institutions are not expected to make monetary contributions to the global fund.

The Cali Fund should support the realization of the objectives of the CBD in developing countries, in particular least developed countries, Small Island Developing States and economies in transition, in particular the conservation and sustainable use of biodiversity, including through the delivery of activities described in NBSAPs, contribute to scientific research on biodiversity, benefit Indigenous Peoples and local communities, including women and youth within those communities, and support the building of capacity in accordance with Article 16 of the Convention, to generate, access, use, analyse and store digital sequence information on genetic resources according to capacity needs. Funding will also be available for these purposes to Indigenous Peoples and local communities in developed countries, where appropriate. Funding to parties will be disbursed through direct allocations to countries. At least half the funding from the global fund should support the self-identified needs of Indigenous Peoples and local communities. Funding will be allocated considering an indicative list of criteria. A formula still needs to be determined for the allocation methodology.

If any other intergovernmental forum decides to make use of the multilateral mechanism, the funding should also support the realization of their objectives.

The decision also includes provisions on mutual supportiveness with other international access and benefit-sharing instruments.

5.6.2 Realization of Farmers' Rights

In addition to establishing the MLS, the International Treaty is the first legally binding international instrument that recognizes contribution that the Indigenous Peoples, local communities and farmers of all regions of the word, particularly those in the centres of origin and crop diversity, have made and will continue to make for the conservation and development of plant genetic resources, which constitute the basis of food and agriculture production throughout the world. Contracting Parties to the International Treaty agreed that the responsibility for realizing Farmers' Rights, as they relate to plant genetic resources for food and agriculture rests with national governments. In accordance with their needs and priorities, each contracting party should, as appropriate, and subject to its national legislation, take measures to protect and promote Farmers' Rights, including: (a) protection of traditional knowledge relevant to plant genetic resources for food and agriculture; (b) the right to equitably participate in sharing benefits arising from the utilization of plant genetic resources for food and agriculture; and (c) the right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture.

Farmers' Rights were first brought onto the international agenda by civil society organizations in the 1980s (e.g. Mooney, 1983) criticizing the asymmetrical distribution of benefits between farmers as providers of PGRFA and commercial plant breeders who generate returns on the basis of such PGRFA. The question of recognition

TABLE 5.5

Number of national measures on Farmers' Rights, by category, as documented in the the International Treaty on Plant Genetic Resources for Food and Agriculture's Inventory as of December 2021

Category of measures for the implementation of Farmers' Rights	Records
1. Recognition of the contribution of Indigenous Peoples, local communities and farmers to the conservation and sustainable use of PGRFA, such as awards and recognition of custodian/guardian farmers	12
2. Financial contributions to support farmers' conservation and sustainable use of PGRFA, such as contributions to benefit-sharing funds	9
3. Approaches to encourage income-generating activities to support farmers' conservation and sustainable use of PGRFA	16
4. Catalogues, registries and other forms of documentation of PGRFA and protection of traditional knowledge	18
5. *In situ*/on-farm conservation and management of PGRFA, such as social and cultural measures, community biodiversity management and conservation sites	10
6. Facilitation of farmers' access to a diversity of PGRFA through community seed banks, seed networks and other measures improving farmers' choices of a wider diversity of PGRFA	44
7. Participatory approaches to research on PGRFA, including characterization and evaluation, participatory plant breeding and variety selection	29
8. Farmers' participation in decision-making at local, national and sub-regional, regional and international levels	15
9. Training, capacity development and public awareness creation	22
10. Legal measures for the implementation of Farmers' Rights, such as legislative measures related to PGRFA	41
11. Other measures/practices	20

Note: PGRFA = plant genetic resources for food and agriculture.
Source: FAO. 2021. *The Inventory.* [Cited 10 December 2021]. https://www.fao.org/plant-treaty/areas-of-work/farmers-rights/inventory-on-frs/en/

and economic compensation is central, and the International Treaty aims to address this through its system of benefit sharing.

Some progress has been made in global processes related to Farmers' Rights since the publication of the SoW2. In 2016, the Governments of Indonesia and Norway co-hosted the Global Consultation on Farmers' Rights in Indonesia as a response to an invitation from the Governing Body of the International Treaty through Resolution 5/2015 (FAO, 2015). This consultation brought together 95 participants from 37 countries across the world (FAO, 2017).

In 2017, the Governing Body established the Ad Hoc Technical Expert Group on Farmers' Rights. This represented a milestone in the discussions on Farmers' Rights. The group was given the mandate to produce an inventory of national measures, best practices and lessons learned from the realization of Farmers' Rights, and – based on this inventory – to develop options for encouraging, guiding and promoting the realization of Farmers' Rights. The inventory is based on submissions received from Contracting Parties and relevant stakeholders, especially farmers' organizations. It reflects the range of measures and practices submitted.

The inventory, which is intended to be updated on a regular basis, was first presented at the Eighth Session of the Governing Body, in November 2019, during which it was also decided to establish an online version of the inventory.[48] The working group was reconvened to continue to work on the options for encouraging, guiding and promoting the realization of Farmers' Rights, which were finalized in 2022 (FAO, 2023a). Both the inventory and the options are organized using the same set of 11 categories (Table 5.5). By the end of 2022, the inventory contained a total of 232 records. Further work on Farmers' Rights included the organization of the Global Symposium on Farmers' Rights in India in September 2023 (FAO, 2023b).

[48] Further information at https://www.fao.org/plant-treaty/areas-of-work/farmers-rights/inventory-on-frs/en/

As of March 2023, 90 countries had submitted reports on their implementation of the International Treaty in accordance with the Compliance Procedures of the International Treaty. Of these, 68 countries (76 percent) stated that they had taken some measures to protect and promote Farmers' Rights. Figure 5.11 shows the proportion of these countries that took action related to specific elements of Farmers' Rights.

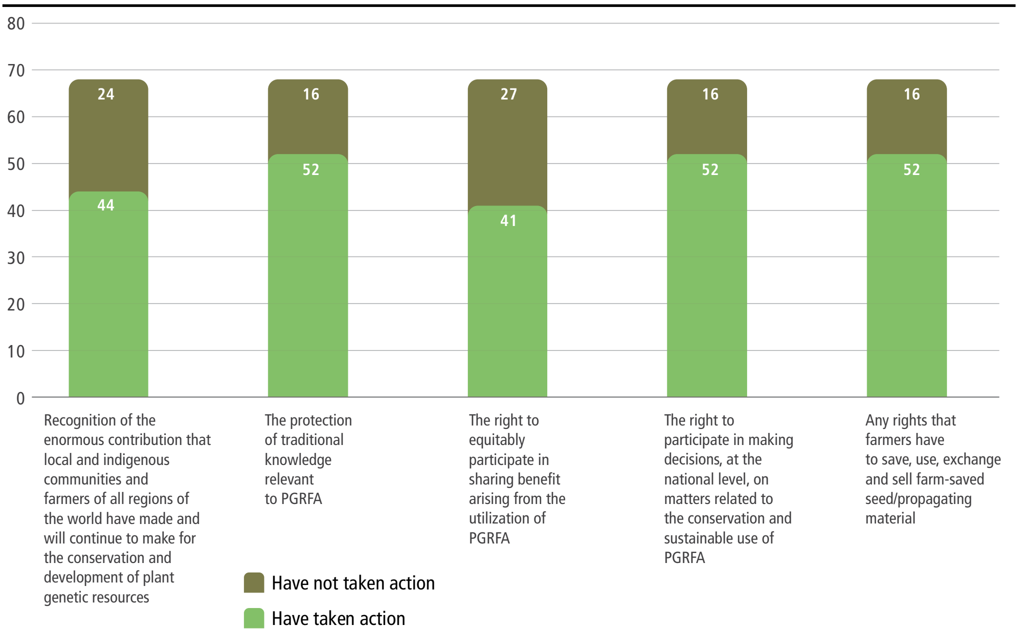
Regional differences in the implementation of Farmers' Rights as indicated in the compliance reports to the International Treaty are summarized in Table 5.6.

Specific examples of recent efforts undertaken at the national level with respect to the realization of Farmers' Rights include:

- In 2010, Norway adjusted its seed regulation to be more accommodating to the approval and use of traditional varieties: the general distinctiveness, uniqueness and stability (DUS) criteria are applied in a less restrictive way and the registration fees for such varieties are reduced.
- In Zambia, the Protection of Traditional Knowledge, Genetic Resources and Expressions of Folklore Act (2016) protects Indigenous People's knowledge associated with PGRFA .
- In the United States, several federal advisory committees provide opportunities for farmers to participate in decision making related to the conservation and sustainable

FIGURE 5.11

Number of countries that had taken action to address specific elements of Farmers' Rights as of 2023



Notes: PGRFA = plant genetic resources for food and agriculture
Source: FAO. 2021. *The Inventory*. [Cited 10 December 2021].
https://www.fao.org/plant-treaty/areas-of-work/farmers-rights/inventory-on-frs/en/

TABLE 5.6
Number and percentage of countries that had taken measures with respect to Farmers' Rights as of 2023, by region

Region	Countries reporting on their implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture	Reporting countries indicating some measure(s) taken to protect and promote Farmers' Rights (No.)	Reporting countries indicating some measure(s) taken to protect and promote Farmers' Right (%)
Northern Africa	2	2	100
Sub-Saharan Africa	22	15	68
Northern America	2	2	100
Latin America and the Caribbean	15	12	80
Asia	22	19	86
Europe	23	17	74
Oceania	4	1	25

Source: FAO. 2021. *The Inventory*. [Cited 10 December 2021]. https://www.fao.org/plant-treaty/areas-of-work/farmers-rights/inventory-on-frs/en/

use of PGRFA, including via the Plant Variety Protection Board and the National Agricultural Research, Extension, Education, and Economics Advisory Board.

- In Rwanda, Law N°005/2016, of 5 July 2016, on the governance of seeds and plant varieties gives farmers the right to save, use, exchange and sell farmer-saved seed or propagated materials irrespective of their origin.
- In several regions in Yemen, farmers have been encouraged through various projects to reuse and share the seeds produced in their fields, with the participation of researchers and extension workers, and to sell them to other farmers.

Another fundamental achievement in the context of Farmers' Rights since the publication of the SoW2 is the 2018 United Nations Declaration on the Rights of Peasants and other People Working in Rural Areas (UN General Assembly, 2018), which refers to the International Treaty in its preamble and adopts text from the International Treaty in its Article 19 on the right to seed (see Box 5.17).

Seed laws in the context of Farmers' Rights

Seed policies, laws and regulations typically include provisions related to the registration of crop varieties, quality standards for seed and planting materials, and the regulation of the production and marketing of such propagules. Such policies, laws and regulations usually also designate competent national authorities to enforce them.

Seed policies, laws and regulations may support or hinder the realization of Farmers' Rights, depending on their restrictiveness with respect to farmers' practices of saving, using, exchanging and selling farm-saved germplasm. A review of the seed legislation texts of 96 countries/regional legislative unions conducted by FAO found that 42 percent of the surveyed countries permitted the sale of uncertified seeds, at least for some crops, while 29 percent explicitly banned the sale of seeds that had not been certified (FAO, 2018). An analysis of the seed laws and policies and regulations across 35 countries in Africa showed that seed laws in 23 countries forbid trade in unregulated seed (ISSD Africa, 2017).

Box 5.17

Declaration on Rights of Peasants and other People Working in Rural Areas adopted by the Human Rights Council in 2018

Article 19

1. Peasants and other people working in rural areas have the right to seeds, … including:
   (a) The right to the protection of traditional knowledge relevant to plant genetic resources for food and agriculture;
   (b) The right to equitably participate in sharing the benefits arising from the utilization of plant genetic resources for food and agriculture;
   (c) The right to participate in the making of decisions on matters relating to the conservation and sustainable use of plant genetic resources for food and agriculture;
   (d) The right to save, use, exchange and sell their farm-saved seed or propagating material.

…

3. States shall take measures to respect, protect and fulfil the right to seeds of peasants and other people working in rural areas.

…

8. States shall ensure that seed policies, plant variety protection and other intellectual property laws, certification schemes and seed marketing laws respect and take into account the rights, needs and realities of peasants and other people working in rural areas.

Source: UN General Assembly. 2018. *Resolution adopted by the Human Rights Council on 28 September 2018.* A/HRC/RES/39/12. https://digitallibrary.un.org/record/1650694?ln=en&v=pdf

The actual level of implementation of seed laws may vary and be subject to administrative interpretation. An FAO review of national implementation found that enforcement was mainly directed towards commercial sales of high-value horticultural or cash crops and did not find evidence of direct enforcement to prevent trade in informal seed systems (FAO, 2021b). Government policy and legislation may have negative impacts on farmers' abilities to engage in commercial seed production and seed marketing (De Jonge *et al*., 2019; Gatto, *et al*., 2021), and many countries in most regions stressed the need to adopt specific legislation that recognizes farmers' seed systems and supports the continued use and marketing of FV/LR (FAO, 2023a).

Seed laws aim to assure the quality of seed in the market, but do not always regulate informal seed systems. Seed laws that include more flexible approaches for regulating informal seed systems may potentially expand opportunities for these systems to market high-quality seed, including seed of FV/LR (Kuhlmann and Dey, 2021). To boost the quality of seeds produced by smaller (including farmer-led) enterprises, and to diversify the options available for marketing such seed, FAO developed the quality declared seed system (FAO, 2016), which has been put into practice in several countries in sub-Saharan Africa. Other countries have introduced legislation based on the related concept of truthfully labelled seed. Both approaches are intended to promote a shift in the responsibility for quality control from the government to the seed producer, assuming that the seed producer has an interest in brand and/or origin reputation and in keeping clients satisfied with the quality of the seed provided (Spielman and Kennedy, 2016). Both approaches may also enhance the use of FV/LR if they succeed in facilitating the marketing of seed from such varieties (FAO, 2021b).

5.7 Participation, community innovations and public awareness

Huge inequalities remain in the way food is produced and distributed, and these are exacerbated by unequal and insecure tenure of land and the growing impact of climate change. Effective participation of food producers, smallholders, Indigenous Peoples and local communities, in decision making related to food systems and in particular to the conservation and sustainable management of crop diversity is a fundamental precondition for the just and equitable realization of the objectives of the GPA2. As discussed in Section 5.5.2, participation in decision making is also a key element of the realization of Farmers' Rights as enshrined in Article 9 of the International Treaty. Moreover, whenever farmers and community contribute to decision making, the conservation and sustainable use of PGRFA benefit.

In this context, promoting and strengthening public awareness of the importance of PGRFA is key to the mobilization of popular opinion and the galvanizing of appropriate political action nationally, regionally and internationally. Priority Activity 18 of the GPA2 targets the promotion of public awareness. An effective PGRFA-related awareness-raising programme requires adequate financial support, strong human resource capacity in communication, lobbying and awareness raising, and well-designed activities targeting a variety of audiences.

This section first considers the state of participation and innovations by farmers and other communities in the management of PGRFA and then discusses the state of public awareness across the world.

5.7.1 Farmer and community innovations and participation

The country reports indicate, albeit unsystematically, that since the publication of the SoW2, countries, national stakeholders and international institutions have been increasingly building mechanisms for the participatory governance of genetic resource management. Some examples are described in Box 5.18. However, there is further scope for establishing such mechanisms or further strengthening those that already exist.

The inclusion of traditional knowledge and the participation of Indigenous Peoples, local communities, peasant farmers and citizens of all genders are increasingly important as efforts to implement the Kunming-Montreal Global Biodiversity Framework begin to take shape, especially those under its Target 22 on participation in decision making and related

Box 5.18
Civil society networks co-developing public policies in Brazil

In Brazil, the National Agroecology Articulation, a network of networks connecting thousands of organizations representing family farmers, Indigenous Peoples and local communities, operates across all of Brazil's regions, focusing on both cultural and biological diversity.[a] The network is dedicated to developing and improving public policies that strengthen agroecology, including seed systems. It works to improve reciprocal connections between government and civil society. Noteworthy are the development of the National Plan for Agroecology and Organic Production in 2012 and the implementation of the Ecoforte programme.[b] Ecoforte, which ran from 2015 to 2022, was developed through a participatory approach and was unique in its focus on territorial agroecology networks. By combining multiple perspectives, the strength and viability of the national policy were successfully put into practice in each territory through a combination of federal and territorial resources, fostering seed houses, seed banks and local markets, and promoting income generation and the defence of biodiversity.

[a] Further information at https://agroecologia.org.br
[b] Further information at https://www.fbb.org.br/pt-br/ra/conteudo/ecoforte

aims (Table 5.6). The increasing recognition of inequalities affecting Indigenous Peoples and local communities, including smallholder and peasant farmers, as well as the valuable contributions that their knowledge and practices provide in the context of conservation, will need to be reflected in more direct ways in all actions taken to implement the GPA2 in harmony with the Kunming-Montreal Global Biodiversity Framework.

Open-source seed initiatives are discussed in Box 5.19.

Farmer seed production

Smallholder seed production requires diverse capacities. Thus, farmers in several countries are organizing themselves, with varying degrees of external support, into local seed producer groups to produce high-quality seed. An initiative supporting farmer participation in breeding and seed systems is described in Box 5.20.

There is some evidence that ministries, extension services and research and breeding institutions, along with farmer organizations, NGOs and national seed companies, are increasingly supporting community-based farmer initiatives for seed production and diffusion, by providing participants with training, seeds from novel crops and varieties and other agricultural inputs, and by buying high-quality locally-produced seed (Dey *et al*., 2022). Some national programmes have begun to reflect the major role of farmer seed production and to address the need to better link farmer and formal seed systems. In the European Union, Regulation 2021/1189[49] allows for organic heterogeneous seed populations to be traded on the European seed market. Until recently, only varieties that met high standards of DUS and were approved through a relatively long and expensive process could be commercialized. Organic, heterogeneous seed populations do not meet these standards, but they have great potential for use in adapting agriculture. Heterogeneity can reduce the risk of crop failure caused by extreme weather and is becoming increasingly important in climate change adaptation efforts. Variability within populations helps crops to adapt to site-specific conditions. The approval of organic seed populations is, therefore, a ground-breaking innovation in the region.

Further actions to link farmer seed systems to the formal market would contribute to efforts to meet the objectives of the GPA2.

[49] Further information at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32021R1189

Box 5.19
Community legal innovations: open source seed initiatives

Recently, a number of open source seed initiatives have been developed, including through support from the third cycle of the International Treaty's Benefit-sharing Fund.[a] These initiatives have grown into a global network of seed-sharing groups, plant breeders, smallholder farmers and civil society organizations that are working to create seed commons. Notable examples include the United States-based Open Source Seed Initiative (OSSI), Agrecol's OpenSourceSeeds in Germany and Bioleft in Argentina as well as organizations and networks in India, Italy, Kenya, Mexico, the Philippines, Thailand, Uganda and the United Republic of Tanzania, many of which are connected through the Global Coalition of Open Source Seed Initiatives (GOSSI).[b]

Together these initiatives support actors who are committed to developing, sharing and distributing seeds that are unencumbered by intellectual property rights or other restrictions on use, through knowledge exchange, training, advocacy and fundraising. Open-source approaches in the context of plant genetic resources for food and agriculture are based on legal innovations that ensure the freedom to save, share and access seeds in perpetuity, for example, through the use of contracts and licences that prohibit the privatization of seed or its progeny distributed as open source.

[a] Further information at https://www.fao.org/plant-treaty/areas-of-work/benefit-sharing-fund/projects-funded/bsf-details/en/c/359497
[b] Further information at https://www.opensourceseeds.org/en/gossi

Box 5.20
The Voluntary Guidelines for Sustainable Soil Management

In West Africa, the McKnight Foundation's Global Collaboration for Resilient Food Systems*[a] has been working on the conservation of genetic diversity in smallholder production systems to improve their resilience, productivity and sustainability. This work combines farmer participatory breeding of sorghum, pearl millet and legume crops with efforts to strengthen local seed systems. The inclusion of genetic resources from different *ex situ* collections in the participatory breeding process is offering new beneficial traits to the farmers.

To foster smallholders' access to, and cultivation of, the newly developed varietal diversity, the programme funded parallel seed systems initiatives led by a farmer research network consisting of several farmer organizations in the Niger, Burkina Faso and Mali, as well as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Funded continuously since 2006, this work builds on local traditions, knowledge and networks related to seeds.

The long-term strengthening and training of farmer-led seed cooperatives helps to improve the availability of quality seeds and diverse farmer-preferred varieties. Positive impacts on productivity, income, and nutrition have been demonstrated by Ambrose (2014); CCRP (2019); and Christinck *et al.* (2016).

Sources: Ambrose, K. 2014. *The influence and added value of the Collaborative Crop Research Program in the Andes*. McKnight Foundation. USA. https://www.ccrp.org/wp-content/uploads/2020/06/ambrose_2014.pdf; CCRP (Collaborative Crop Research Program). 2019. *Advancing together.* McKnight Foundation. USA. https://www.ccrp.org/wp-content/uploads/2019/05/Advancing-Together.pdf; Christinck, A., Doka, M.D., Horneber, G., Rugunda, G.K., Palé, G. & Whitney, C.W. 2016. *From breeding to nutrition*. McKnight Foundation. USA. https://www.ccrp.org/wp-content/uploads/2020/06/ofsp_case_study.pdf

[a] Further information at https://www.ccrp.org

Box 5.21
Supporting farmers as breeders

The Sowing Diversity = Harvesting Security (SD=HS) programme, a joint undertaking of Oxfam Novib and civil society partners, is working to promote a global food system that supports Ffarmers' Rights and guarantees food and nutrition security through the sustainable management of crops. To this end, the programme has developed alliances with non-governmental organizations, government institutions, academic bodies and national breeding and research institutes to bring together expertise in quality seed development, policies and regulation, local seed enterprise development and public–private partnerships. Specifically, SD=HS assists smallholder farmers, Indigenous Peoples and local communities to access, develop and use plant genetic resources for food and agriculture.

Active in eight countries (China, Guatemala, the Lao People's Democratic Republic, Nepal, Peru, Uganda, Zambia and Zimbabwe), the programme focuses on four goals: (1) facilitating farmers' crop improvement and adaptation to support sustainable use of plant genetic resources for food and agriculture; (2) helping farmer seed enterprises to enhance livelihoods and seed security; (3) addressing nutrition through the use and management of neglected and underutilized species; and (4) promoting an enabling policy and institutional environment for farmers' seed systems and the implementation of Farmers' Rights.

Under SD=HS, partners have established 1 050 farmer field schools, trained 35 000 smallholder farmers, including those who are Indigenous Peoples, with equal gender representation, and selected and improved 392 crop varieties for climate resilience. A total of 200 000 people were reached directly.

Source: SD=HS (Sowing Diversity = Harvesting Security). 2024. *Sowing Diversity = Harvesting Security*. [Cited 19 December 2024]. https://sdhsprogram.org/

5.7.2 Public awareness

Seventy-one out of 89 reporting countries indicate that they established or strengthened public-awareness programmes that actively promoted PGRFA conservation and utilization during the reporting period. No formal programmes were reported from Northern America, while in the other regions, the proportion of countries that reported a programme ranged from 63 percent (Latin America and the Caribbean) to 90 percent (sub-Saharan Africa). These programmes led to the implementation of an increased number of awareness-raising activities by a variety of stakeholders at all levels (Figure 5.12), ranging from seed fairs and open field days to policy dialogues, television talk shows, and the compilation of recipe books focused on native edible species. These various activities and outputs resulted in greater knowledge and understanding of the importance and multiple benefits of PGRFA.

In some countries, increased public awareness was reflected in the better documentation of crops and native varieties, including through the development of national catalogues of local species and varieties, for example in Canada, Madagascar, Nepal and the Kingdom of the Netherlands, or in newly adopted national strategies or legislation. For instance, in Guatemala, maize was recognized as a "Natural and Cultural Heritage" by a legislative decree adopted in 2014, thereby promoting the identification, classification, documentation, protection and dissemination of uses, traditions and knowledge related to maize. Higher public awareness of the importance of PGRFA is also reflected in the growing involvement of new actors who have strong links with farmers and rural communities, such as NGOs, social movements, civil society organizations and seed networks. For instance, at the international scale, Slow Food and La Vía Campesina have played important roles in promoting local food cultures and traditions and supporting local food and seed networks in many countries.

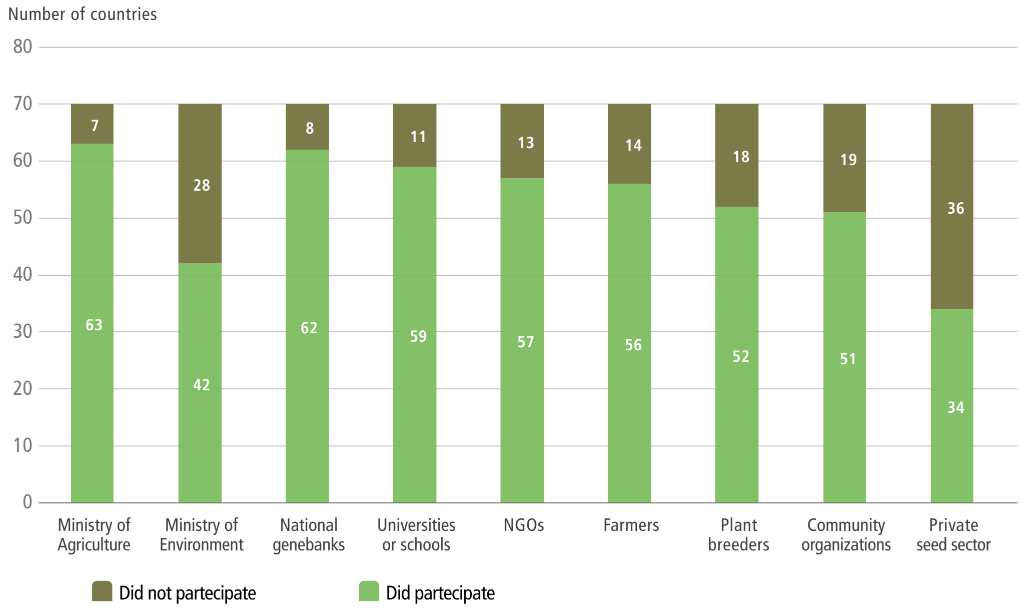
The country reports indicate that greater attention has been paid to local crops since the publication of the SoW2. Local, regional and national seed and diversity fairs provide important platforms for raising awareness of the importance of PGRFA, especially local crops, by showcasing the diversity of native varieties, local seeds and food products, and by engaging the public, including through workshops, field days, food tastings and artistic performances. Seed and diversity fairs also provide a platform for exchanging seeds, knowledge and experience among farmers.

Genebanks also play an important role in displaying the material they maintain, holding open days, giving talks and providing training to farmers, students and researchers. The existence of the SGSV has also provided numerous opportunities for raising public awareness internationally. Other important activities by national programmes include the organization of on-farm demonstration plots, awareness campaigns, exhibitions, research conferences, training and awareness workshops that support the dissemination of research findings to specific audiences.

In many countries, dissemination of PGRFA-related information is extended to a wider population through radio, television and the websites of public institutions, research centres and genebanks. An important development in recent years has been greater diversity in the media used for communications, with digital and social media platforms such as X, Facebook and YouTube increasing in importance and often reaching and engaging a much larger audience than traditional media, especially young people.

However, despite the increased number of awareness-raising activities in most regions, knowledge and understanding of the importance of PGRFA is still low, especially among policymakers and the wider population but also among the research community and professionals in the agrifood sector. Many countries have not yet adopted national public awareness plans or

FIGURE 5.12
Participation of different stakeholder groups in public-awareness programmes



Notes: NGOs = non-governmental organizations. Based on 70 country reports.

programmes, and awareness-raising activities are often carried out in an unstructured way on an ad hoc basis within existing research projects.

Regional assessment

Northern Africa

In Egypt and Tunisia, the only two countries from this region that provided information on this topic, genebank staff were actively involved during the reporting period in awareness-raising activities, including open days and information days, fairs, commemorative days and events such as the International Day for Biological Diversity, or in producing awareness-raising materials such as online documentary videos. Moreover, farmer and civil society networks have become more active in the promotion of conservation and sustainable use of traditional local varieties. Some examples from Tunisia are presented in Box 5.22.

Box 5.22
Public awareness-raising efforts in Tunisia

Tunisia's National Strategy for the Development and Sustainable Management of Forests and Rangelands (2015–2024) includes an information component that aims to raise public awareness about protected areas and has a specific focus on women.

The implementation of the Sustainable Management of Oasis Ecosystems project led to the organization of a number of national and international fairs and festivals, including the first fair on biodiversity and the processing industries, the first international forum on oasis dwellers, the first festival of Kebili dates and the first international forum on dates and palms.

Seed Caravan, launched in 2018 by the Tunisian Association of Permaculture, aims to identify the farmers' varieties existing across the country.

The Peasant Seeds network, which has more than 16 800 members, uses social networks to provide a platform for the exchange of local seeds and knowledge.

Sources: Data provided by Tunisia.

Sub-Saharan Africa

In sub-Saharan Africa, seed fairs and agricultural shows are a popular means of raising awareness on seed varieties. Nearly 70 percent of the reporting countries (15 out of 22) indicate that such events were organized during the reporting period, including the first fair on farm-saved seed in Cameroon. These fairs contributed to raising the profile of traditional food and increasing awareness of their nutritional value and their importance in promoting healthy diets and eating habits. In Togo and Zimbabwe, such fairs also act as platforms for seed and knowledge exchange and thereby helped to increase seed diversity, especially in rural and difficult-to-reach areas. The growing interest of civil society and the farming community in traditional local crops and varieties has given rise to new initiatives led by a range of associations and networks involved in the conservation and sustainable use of PGRFA.

In the Niger, the NGO Raya Karkara, in collaboration with the Coalition for the Protection of Africa's Genetic Heritage, organized caravans and awareness activities on the importance of local varieties and Farmers' Rights in several regions of the country in 2018. The annual National Farmers' Forum Togo brings together stakeholders in that country to promote endangered species and underutilized local species such as fonio and sesame.

According to about 60 percent of the reporting countries in the region (13 out of 22), the use of local and national mass media to promote awareness of the importance of PGRFA, including broadcast, print and digital media, has greatly increased in the past decade. For example, in Namibia, Green Horizon is a weekly agricultural magazine television programme created in 2013 that has established itself as a popular educational show. In Zambia, farmer seed systems are frequently addressed on radio and television programmes. In Botswana, Ethiopia, Ghana, Kenya, Namibia, Senegal, South Africa and Togo, many publications targeting different stakeholders have been developed and disseminated, including online. These include scientific books and articles as well as fliers, newsletters, leaflets, fact sheets, policy briefs, posters, brochures, booklets, including on Indigenous Peoples' food recipes, and practical handbooks for developing and supporting CSBs. An example of the use of digital platforms is presented in Box 5.23.

Northern America

In Canada, a number of initiatives and activities aimed at raising awareness of the importance of PGRFA took place during the reporting period. Community-based seed library initiatives were established. A virtual symposium to mark the fiftieth anniversary of the national genebank was held in 2020 and brought together 400 participants from 27 countries. Information on hundreds of community-organized events hosting seed exchanges, workshops and vendors is gathered on a dedicated website.

Latin America and the Caribbean

Most countries from Latin America and the Caribbean report increased awareness activities

Box 5.23

Awareness raising via digital platforms in Zimbabwe

The Kurima Mari mobile app, pioneered by Welthungerhilfe (WHH) and partners under the Livelihoods and Food Security Programme funded by the United Kingdom's Department for International Development, has been used extensively in Zimbabwe's midlands province to raise awareness of various agronomic practices in target value chains, such as local small grains (sorghum and pearl millet) and bambara nuts as well as biofortified crops such as bean variety Nua45 and vitamin-enriched orange maize. The Zimbabwe Agricultural Knowledge and Innovation Services (ZAKIS) also uses digital platforms to raise awareness on crops grown by smallholder farmers.

Sources: Data provided by Zimbabwe.

since the publication of the SoW2, and this has led to better understanding of the importance of PGRFA among decision makers and in civil society in the region. As in other regions, greater attention has been paid to promoting local genetic resources, including crop varieties. This is shown in the increase in the number of local, regional and national agricultural fairs, seed fairs and gastronomic festivals organized in many countries, including Argentina, Brazil, Cuba, Ecuador, Guatemala and Mexico, often with the support of NGOs and seed networks.

Other initiatives reflected the increasing attention being paid to the promotion of local crop varieties and their seeds. These included efforts to promote the consumption of local foods and products derived from native plants. NGOs, social movements and civil society organizations played an important role in these activities. Some examples from Guatemala are described in Box 5.24.

In Brazil, the Society of Genetic Resources, created in 2008, encouraged the development of regional and national genetic resources networks, associations and NGOs that raise awareness and promote family farming, for example AS-PTA Family Agriculture and Agroecology and the Ecovida network, which brings together 4 500 families. In Argentina, the ProHuerta Programme implemented by the National Institute of Agricultural Technology (INTA) promoted the development of family, school and community gardens, resulting in the establishment of more than 600 000 garden providing seeds for food self-sufficiency. It also created spaces for the exchange of plants, seeds, knowledge and practices at various fairs. In Peru, consumers' interest in local food led to a "gastronomic turn", with chefs, local communities and the academic sector promoting the consumption of food derived from local varieties. Joint efforts by farmers and local governments in Lima and Huánuco to organize ecological and diversity fairs where producers directly marketed their products were particularly successful.

Box 5.24
Awareness-raising activities by community organizations in Guatemala

In Guatemala, community organizations have been actively involved in the development of manuals and other publications, posters and training modules on the importance of native varieties of maize and beans and their *in situ* conservation. They have also promoted the establishment of family, community and school gardens containing native species. A model for sustainable healthy schools involving the creation of school gardens, food purchases from local family farms, and food and nutrition education was implemented in 421 schools in San Marcos, Huehuetenango and Chiquimula. This has helped support family farming and provided farmers with the opportunity to promote their products for use in school meals.

Source: Data provided by Guatemala.

Scientific conferences and symposia open to the public also contributed to knowledge dissemination and awareness raising among the public and the scientific community. Scientific congresses on PGRFA in Mexico are described in Box 5.25.

Asia

In a few countries, such as Armenia, Jordan, Kyrgyzstan, Tajikistan and Yemen, the reporting period saw an increase in the number of awareness-raising activities and projects implemented with the support of, or in collaboration with, international organizations and bilateral donors. Some examples are described in Box 5.26. Public foundations were also increasingly engaged in awareness raising activities. A growing interest in local crops and varieties was reflected in the increased number of activities and initiatives promoting awareness of the importance of their conservation and sustainable use. Seed fairs, diversity fairs, and food fairs and festivals, often involving crop

Box 5.25
Scientific congresses on plant genetic resources for food and agriculture in Mexico

In Mexico, the second Fair of Agrodiversity and Agroproducts was held in 2013, in commemoration of the eleventh anniversary of the creation of the National System for Plant Genetic Resources for Food and Agriculture. It brought together more than 300 producers from all over the country, as well as other stakeholders representing more than 60 organizations, to disseminate knowledge and good practices related to conservation and use. In addition to a variety of food tastings and workshops, it included a symposium entitled "Diversity and Uses of Plant Genetic Resources in Mexico and Latin America: Economic Importance and Environmental Sustainability" that brought together experts, researchers, academics, seed inspectors and staff from international organizations, including FAO and the International Center for Tropical Agriculture (CIAT).

In 2015, the Chapingo Autonomous University, in coordination with the National Seed Inspection and Certification Service, organized the Second Congress on Phytogenetic Resources and the First International Congress on the Conservation and Sustainable Use of Agrobiodiversity. This provided the opportunity to disseminate recent research on *in situ* conservation (genetic erosion, participatory plant breeding, sustainable conservation models and traditional systems), *ex situ* conservation (core collections and the use of ecogeography in the context of genebanks) and sustainable use (denominations of origin, climate change and genetic improvement).

In 2017, Mexico hosted the Symposium on Genetic Resources for the Americas and the Caribbean, at which regional priorities for the conservation and sustainable use of plant genetic resources for food and agriculture were elaborated.

Source: Data provided by Mexico.

Box 5.26
Examples of awareness-raising activities in Asian countries

Armenia: The UNDP/GEF project Creating Global Environmental Benefits through Environmental Education and Raising Awareness of Stakeholders (2015–2019) greatly contributed to raising public awareness of the importance of biodiversity through the organization of round tables, the launch of education campaigns and the elaboration of strategies and methodologies for the conservation and sustainable use of plant genetic resources for food and agriculture.

Kyrgyzstan: The public foundation, the Agency of Development Initiatives, within the framework of the project *Dyikan Muras* (Farmer's Legacy) provides training and consultations to farmers, organizes seminars to disseminate knowledge on the cultivation of local vegetables for seed production, and holds field days to facilitate the exchange of experiences between farmers. The annual apricot festival in the Issyk Kul region aims to promote Issyk Kul apricots as well as agrotourism. Seminars, master classes, exhibitions and contests for the best apricot products are organized.

Türkiye: The project *Mirasımız Yerel Tohum* (Our heritage: local seeds), initiated by the Ministry of Agriculture and Forestry in 2017, aims to raise awareness of local seeds from Anatolia. Festivals promoting wild edible plants and local crops and varieties are held every year.

Source: Data provided by Armenia, Kyrgyzstan and Türkiye.

contests and farmers award ceremonies, occurred in several countries, including India, Indonesia, Kyrgyzstan, Lebanon, Nepal, Türkiye and Yemen. An example from India is described in Box 5.27. Public awareness of the importance of PGRFA, including local crops and varieties, was supported via television, radio, digital media and social networks in Armenia, Bangladesh, India, Jordan, Lebanon and the Philippines.

Box 5.27
India's National Plant Genome Saviour Awards

The Plant Genome Saviour Community Award is conferred every year by the Indian Protection of Plant Varieties and Farmers' Rights Authority. This national award recognizes the efforts of Indian groups or communities of farmers that contribute to the conservation or improvement of plant genetic resources for food and agriculture (PGRFA). Since 2012, the authority has also conferred the Plant Genome Saviour Farmer Reward, which is accompanied by a financial prize, and a farmer recognition award to individual farmers who have engaged in exceptional efforts in the context of conservation of farmers' varieties/ landraces and crop wild relatives. The genetic resources related to the awards are then explored for further use. The awards not only recognize and compensate farmers for their contributions to the development and conservation of PGRFA, they also greatly help to raise awareness among the wider public.

Source: Ministry of Agriculture. 2012. *Plant genome savior community award*. Government of India. New Delhi. https://icar.org.in/sites/default/files/inline-files/English-Form-PGSCA-19-03-2012.pdf

Box 5.28
Collaborative learning activities for seed savers in Europe

In 2018, the seed savers organizations of the Baltic states and Denmark launched the international project Growing Seed Savers: Baltic-Nordic Seed Savers' Education Innovation[a] funded by the Nordic Council of Ministers' programme NORDPLUS. The project aims to create a local seed network to support heritage varieties and their growers by providing training to disseminate knowledge about agrobiodiversity, seed-saving practices and seed legislation as well as through the involvement of farmers, gardeners, chefs and consumers in the collection, management and sustainable use of heritage seed varieties.

In Norway, the organization KVANN, Norwegian seed savers,[b] which was created in 2016, provides a forum through which its more than 800 members can access material and share information, experiences and expertise related to the conservation of plant diversity.

[a] Further information at https://growingseedsavers.org
[b] Further information at https://kvann.no

A larger number of publications, including newsletters, brochures, booklets, leaflets, production guides and articles in newspapers, magazines and scientific journals, were widely distributed to increase awareness of PGRFA. These included publications on native crop diversity in Nepal, on indigenous vegetables in the Philippines and on CWR in Armenia.

Europe

Many countries, including Belarus, Czechia, Germany, Ireland, Norway, Portugal, Sweden and Switzerland, report increased public awareness of the importance of PGRFA during the reporting period, including in particular awareness of organic agriculture, on-farm conservation, and heirloom crops and cultivars. The information-sharing activities of organizations of seed savers in northern Europe are described in Box 5.28.

A range of private and public actors and civil society organizations carried out targeted dissemination and information activities aimed at raising awareness about the importance of PGRFA among farmers and other groups, including children and young people. These included the organization of workshops, conferences, demonstration gardens, exhibitions and fairs in Czechia, Estonia, France, Germany, Hungary, the Kingdom of the Netherlands, Portugal, the Republic of Moldova, Switzerland, and the United Kingdom. Relevant projects included the GEF/SGP-funded Environmental Education for Public Awareness on Biodiversity Protection in the Republic of Moldova (2017–2019), which aimed principally to raise the level of education and public awareness of the conservation of PGRFA at the country's Environmental Education Centre.

Awareness-raising activities targeting the public in the region also utilized the press, radio and television. For example, in Switzerland, the Mission B campaign was launched on national radio and television in 2019 to address the decline of biodiversity. In many countries, including Czechia, Estonia, France, Germany and Switzerland, social media and the internet played an increasingly important role. Market-based mechanisms also played an important role in promoting local varieties in the region. For instance, in Switzerland, the ProSpecieRara quality label is a private, controlled and certified quality label used to promote endangered and rare varieties and breeds on the market and to recognize the contribution and commitment of livestock keepers and variety managers.

Oceania

In Papua New Guinea, public awareness of PGRFA was raised during the reporting period via annual provincial agricultural shows, seminars and workshops and via the dissemination of information through local and national print and digital media. The National Agriculture Research Institute hosted events, demonstrations and hands-on training for farmers.

5.8 Changes since *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*

All aspects of human and institutional capacity for managing PGRFA have advanced. The following subsections highlight some significant developments.

National programmes

- Progress has been made in the establishment and development of national programmes for the management of PGRFA. The development of NBSAPs has played a catalysing role in this regard.
- While great efforts have been made in some countries to build and strengthen national programmes and to improve coordination among national stakeholders, a significant amount of work on PGRFA has occurred through ad hoc time-bound projects rather than being integrated into coherent programmes.
- NISMs have fallen into disuse. Some countries have developed appropriate alternatives that serve both for information sharing among national stakeholders and for reporting to international institutions, including on implementation of the GPA2.

Training and education

- The availability of human resources for the management of PGRFA has slightly improved, though progress has been uneven across key areas of conservation and sustainable use, as well as among regions and countries. In some countries, the reporting period saw the creation of new universities and other educational institutions, and the introduction of new courses and programmes related to PGRFA. However, many countries lack a capacity-building programme in place to specifically address PGRFA conservation and use, and gaps remain in the quality of training provision.
- Alongside universities and vocational agricultural schools, new actors have become increasingly involved in training and capacity development, for example botanical gardens, genebanks, seed networks, research institutes, regional and international organizations, NGOs, foundations and museums.
- Cooperation among and between educational institutions, seed networks, research institutes, and regional and international genebanks has increased, leading to the establishment of joint educational and research activities.
- The increased use of online tools and platforms has enabled the development of a range of innovative teaching materials,

including educational videos and learning resources, and has contributed to wider distribution of training opportunities through remote participation.

PGRFA networks

- PGRFA networks have remained important hubs of activity and promotion for conservation and sustainable use. While some important regional networks have had to pause or cease their activities, others have sprung up or renewed their efforts.
- The important benefits of international collaboration are now widely recognized by stakeholders.
- The number of publications produced through networks substantially increased during the reporting period.

Other forms of international collaboration

- In addition to the International Treaty, the conservation and sustainable use of PGRFA, along with ABS issues in this sector, have been prioritized in the context of several international agreements and initiatives in recent years, including under the Kunming-Montreal Global Biodiversity Framework, which strengthens linkages between all the biodiversity-related conventions.
- Overall, there are now more international initiatives that focus on, or are relevant to, PGRFA than in previous reports, including initiatives led by civil society.
- As public finance for PGRFA dwindles, innovative resource mobilization is a key focus of major PGRFA-related institutions such as the Crop Trust and the International Treaty.

Information systems for plant genetic resources for food and agriculture

- Information systems have expanded and proliferated, and cross-platform interoperability and data-sharing initiatives herald further advances. The development of GLIS (including Genesys) and GG-CE are notable examples. The increasing number of countries reporting MCPD-standardized accession-level data on SDG Indicator 2.5.1.a reflects progress at the country level in documenting *ex situ* germplasm holdings and making the information publicly accessible.

Monitoring systems for genetic erosion

- Awareness of the importance of monitoring mechanisms for genetic erosion, especially in the context of *in situ* conservation, has increased.
- Recognition of the benefits of combining *ex situ* and *in situ* conservation efforts has grown.

Access and benefit-sharing

- Progress has been made in the development of access to PGRFA at the international level, notably through an increase in the number of accessions made available under the MLS. International agricultural research centres with agreements with the Governing Body of the International Treaty, as well as some national genebanks, now make all their PGRFA available under the MLS, and there has been an increase in the number of SMTAs reported per year. Moderate progress has been made in the development of national policy and legislative measures for ABS.
- Awareness of the importance of benefit-sharing and the challenges involved in its implementation is now widespread. Existing benefit-sharing mechanisms are in the process of being improved. Since 2013, a process aimed at improving the functioning of the MLS has been in place under the International Treaty.
- The significance of DSI in the plant sciences and in the use of associated technologies has increased exponentially in recent years. The sharing of benefits arising from the use of DSI is mandated under the Kunming-Montreal Global Biodiversity Framework.

Farmers' Rights

- Farmers' Rights have seen substantial development in recent years, not least through the role of the International Treaty and other international instruments.

Participation

- The participation of farmers, Indigenous Peoples, local communities and the wider public in PGRFA-related decision making has increased. International institutions, governments and various national stakeholders are increasingly building mechanisms for participatory governance of the management of PGRFA.
- Target 22 of the Kunming-Montreal Global Biodiversity Framework enshrines full and equitable participationof Indigenous Peoples and local communities in decision-making.

Public awareness

- The number of PGRFA-related awareness-raising activities has increased, and public awareness has grown significantly. The importance of PGRFA and the significance of challenges related to their management are now more widely understood by decision makers, civil society and farming communities than ever before. In particular, greater attention has been drawn to the importance of local crop diversity by raising awareness of native varieties, local seeds and traditional food products and their nutritional value.
- Dissemination of PGRFA-related information has increasingly involved new actors that have strong links with farmers and rural communities, such as NGOs, social movements, civil society organizations and seed networks.
- The increased use of digital and social media platforms has contributed to the dissemination of information on PGRFA to a much broader audience, including young people.

5.9 Gaps and needs

Despite progress made in the context of human and institutional capacities for PGRFA since the publication of the SoW2, significant gaps remain across all the regions of the world.

National programmes

- Even where they exist or are in the process of being developed, national programmes for the management of PGRFA are still not adequately implemented in most countries. PGRFA work is still often realized through ad hoc, time-bound projects, with individual initiatives needing to be better connected and coordinated. Collaboration among national stakeholders and institutions is frequently weak. Initiatives driven by civil society organizations are not adequately supported or sufficiently integrated into national programmes.
- PGRFA strategies are often incorporated into countries' NBSAPs, and there are often gaps in terms of the development of PGRFA-specific strategies and action plans that account for the particular challenges involved in managing these resources.
- The lack of stable, continuous funding, and the predominance of short-term, project-based financing, is a key constraint to the development of coherent and effective national programmes and undermines knowledge transfer, capacity building and institutional evolution.

Training and education

- Despite significant progress in this area, the improvement of academic institutions and the further development of educational programmes remains a persistent need across all regions. Some countries lack comprehensive programmes on plant breeding, genetic improvement and biotechnology. Targeted training courses in all technical and legal aspects of PGRFA management need to be made available to

larger numbers of professionals, farmers and members of civil society.
- In many countries, there is a need to ensure that retiring PGRFA experts are replaced by a younger generation of professionals. Capacity building and knowledge transfer are still significant challenges, especially given that some subjects such as plant taxonomy and traditional plant breeding seem to be less appealing to younger generations.
- Shortages of research funding, including for scholarships and postdoctoral fellowships and for long-term breeding programmes, are a significant constraint to capacity building.
- Weaknesses in PGRFA-related collaboration and partnerships within and between national higher education institutions, research centres, networks and international institutions remain unaddressed in many countries.

Plant genetic resources for food and agriculture networks
- The benefits provided by international collaboration in the field of PGRFA management are still unevenly distributed and not equally accessible to all, especially where the availability of financial resources is inconsistent.
- Collaboration among stakeholders within PGRFA-related networks needs to be strengthened as do the management of networks at the regional and international levels and coordination among them.
- Many PGRFA-related networks are managed on a voluntary basis, which implies fragility and dependence on project funds with a short time horizon.

Other forms of international collaboration
- While PGRFA-related collaboration and joint initiatives at the international level are increasing, there is still scope to improve their coordination and make them more synergetic. This is particularly important given that many global goals and targets related to biodiversity have not been met within their timeframes.
- Dwindling funds are a key constraint to the effective implementation of all types of PGRFA-related activities in all regions. In many cases gaps are being plugged with project funding rather than dedicated budget streams. Key PGRFA institutions, notably the International Treaty and the Crop Trust, are exploring innovative resource-mobilization opportunities. However, effective solutions remain to be found.

Information systems for plant genetic resources for food and agriculture
- There are still important geographical and thematic gaps in the coverage of PGRFA-related information systems, especially where CWR, WFP and FV/LR are concerned. Asymmetries in technological capacities are significant hurdles to equal access to, and effective management of, PGRFA-related information.
- Although progress has been made, a significant proportion of *ex situ* conserved accessions have not been characterized or evaluated, or existing data have not been published. Where characterization and evaluation information exists, it is often not publicly accessible. Gaps are even more prevalent in the case of information on the geographical distribution of CWR, WFP and FV/LR. Systematic surveying and monitoring to address knowledge gaps in this field, as well as access to these data are particularly needed.
- While progress has been made in terms of improving the interoperability of existing information systems through shared, open standards, further work on this is needed.
- Key constraints to the strengthening of information systems include gaps in technical capacity in taxonomy, information

management and bioinformatics, gaps in digital infrastructure, particularly in the case of genebanks, and gaps in funding.

Monitoring systems for genetic erosion

- Monitoring mechanisms for genetic erosion, especially in the context of *in situ* conservation and on-farm management, remain in urgent need of development and implementation in most countries and regions. Few countries have put in place a national system for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Most countries lack national policies addressing this issue.
- Surveys and baseline studies are urgently needed in many countries, and there is a concomitant need to develop indicators for genetic vulnerability and erosion that feed into early-warning systems.
- Lack of resources and lack of long-term funding as well as weak coordination among stakeholders remain significant hurdles to efforts to minimize genetic erosion.

Access and benefit sharing

- While significant progress has been made in terms of improving access to PGRFA at the international level, concomitant benefit sharing is relatively underdeveloped. Existing mechanisms, including the MLS, need to be improved.
- ABS regulation at the national level needs further development in many countries.

Farmers' Rights

- While Farmers' Rights have seen substantial development in recent years, national implementation needs to be improved. There are still crucial contradictions between Farmers' Rights and the implementation of seed laws in many countries, arising at least partly because of a lack of awareness on the part of decision makers.

Participation

- The participation of farmers, Indigenous Peoples, local communities, civil society and the wider public in decision making and in the development of solutions to PGRFA-related challenges needs to be further improved in most institutional and national contexts.
- Capacities for effective facilitation of participatory processes need to be built at all scales.

Public awareness

- Although significant improvements have been achieved, awareness of the importance of PGRFA and understanding of challenges related to their management still need to be strengthened, especially among professionals and policymakers in other sectors – including those working on environmental issues, trade and health – to maximize synergies and catalyse changes in an integrated fashion. Only a very few countries have national communication strategies and targeted public-awareness programmes on the value of PGRFA and the threats affecting them.
- Interinstitutional coordination, collaboration and partnerships related to communication activities, including collaboration with media organizations, are still weak across all regions, resulting in shortcomings in information dissemination. There are also still gaps with respect to the provision of information that is adapted to a diverse range of audiences and available in a range of local languages.
- The lack of funding and permanent budgets for communication remains a key constraint to public awareness-raising activities.

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ANNEXES

Annex 1

List of countries that provided information for the preparation of *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture*

Legend	
Rp1	Reporting period January 2012 – June 2014
Rp2	Reporting period July 2014 – December 2019
Rp3	Reporting period January 2012 – December 2019
Y	Annual report provided at least once over the period 2014–2022

List of countries that provided information for the preparation ofThe Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture

Countries	*In situ* conservation and management		*Ex situ* conservation			Sustainable use		Institutional and human capacities	
	Data reports	Summative narrative reports	Data reports	Summative narrative reports	SDG 2.5.1.a reports	Data reports	Summative narrative reports	Data reports	Summative narrative reports
Afghanistan					Y				
Albania	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Argentina	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Armenia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Australia	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1	
Austria					Y				
Azerbaijan	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Banglades[1]	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Belarus	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Belgium					Y				
Benin	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2		Rp1; Rp2	
Bhutan	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1; Rp2	
Bolivia (Plurinational State of)					Y	Rp1		Rp1	
Bosnia and Herzegovina					Y				
Botswana	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Brazil	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Bulgaria	Rp1		Rp1		Y	Rp1		Rp1	
Cameroon	Rp2	Rp3		Rp3		Rp2	Rp3	Rp2	Rp3
Canada[2]			Rp1; Rp2		Y	Rp1; Rp2		Rp1; Rp2	
Chad			Rp2			Rp2		Rp2	
Chile	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
China	Rp2		Rp2			Rp2		Rp2	
Colombia	Rp2	Rp3	Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Congo			Rp1						
Cook Islands						Rp1		Rp1; Rp2	
Costa Rica	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Croatia	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1; Rp2	
Cuba	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Cyprus	Rp1; Rp2	Rp3	Rp1; Rp2		Y	Rp1; Rp2		Rp1	
Czechia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Democratic Republic of the Congo	Rp2	Rp3	Rp2	Rp3			Rp3	Rp2	Rp3

[1] Also submitted a stand-alone country report.
[2] Also submitted a stand-alone country report.

Countries	*In situ* conservation and management		*Ex situ* conservation			Sustainable use		Institutional and human capacities	
	Data reports	Summative narrative reports	Data reports	Summative narrative reports	SDG 2.5.1.a reports	Data reports	Summative narrative reports	Data reports	Summative narrative reports
Denmark					Y				
Ecuador	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Egypt	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
El Salvador	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Eritrea	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Estonia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Eswatini					Y				
Ethiopia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Finland	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
France	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Georgia					Y				
Germany	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Ghana	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Greece	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1; Rp2	
Guatemala	Rp1; Rp2	Rp3	Rp1	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Guinea	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Guyana	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Honduras					Y				
Hungary	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp1; Rp2	Rp3
India	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Indonesia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Iran (Islamic Republic of)	Rp1		Rp1; Rp2			Rp1; Rp2		Rp1; Rp2	
Ireland	Rp1				Y			Rp1	Rp3
Israel					Y				
Italy	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Japan	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Jordan	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Kenya	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Kyrgyzstan	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Latvia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Lebanon	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Lesotho		Rp3			Y				
Libya			Rp1		Y			Rp1	
Lithuania					Y				
Madagascar	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3

(Cont.)

Countries	*In situ* conservation and management		*Ex situ* conservation			Sustainable use		Institutional and human capacities	
	Data reports	Summative narrative reports	Data reports	Summative narrative reports	SDG 2.5.1.a reports	Data reports	Summative narrative reports	Data reports	Summative narrative reports
Malawi	Rp1		Rp1		Y	Rp1		Rp1	
Malaysia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Mali	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Malta					Y				
Mauritania					Y				
Mexico	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Mongolia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Montenegro					Y				
Morocco	Rp1; Rp2		Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	
Myanmar		Rp3	Rp2	Rp3	Y		Rp3		Rp3
Namibia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Nepal	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Netherlands (Kingdom of the)	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
New Zealand					Y				
Nicaragua	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Niger	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Nigeria	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
North Macedonia					Y				
Norway	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Oman[3]									
Pakistan	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1; Rp2	
Panama	Rp1		Rp1		Y	Rp1		Rp1	
Papua New Guinea	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Peru	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Philippines	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Poland	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Portugal	Rp2	Rp3	Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Qatar		Rp3	Rp2		Y				
Republic of Moldova	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Romania	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Russian Federation					Y				
Saint Lucia		Rp3		Rp3			Rp3		Rp3
Senegal	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3

[3] Also submitted a stand-alone country report.

Countries	*In situ* conservation and management		*Ex situ* conservation			Sustainable use		Institutional and human capacities	
	Data reports	Summative narrative reports	Data reports	Summative narrative reports	SDG 2.5.1.a reports	Data reports	Summative narrative reports	Data reports	Summative narrative reports
Serbia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Slovakia					Y				
Slovenia					Y				
South Africa	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Spain	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Sri Lanka	Rp1; Rp2		Rp1; Rp2		Y	Rp1; Rp2		Rp1	
Sudan	Rp1		Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Suriname					Y				
Sweden	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Switzerland	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Tajikistan	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Thailand			Rp1		Y	Rp1		Rp1	
Togo	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Trinidad and Tobago	Rp1; Rp2	Rp3	Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Tunisia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Türkiye	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Uganda	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Ukraine					Y				
United Kingdom	Rp1; Rp2	Rp3	Rp1	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
United Republic of Tanzania	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
United States					Y				
Uruguay	Rp1; Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp2	Rp3
Uzbekistan	Rp1; Rp2	Rp3	Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Venezuela (Bolivarian Republic of)		Rp3		Rp3			Rp3		Rp3
Viet Nam			Rp2		Y			Rp2	
Yemen	Rp1	Rp3	Rp1; Rp2	Rp3		Rp1	Rp3	Rp1; Rp2	Rp3
Zambia	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3	Y	Rp1; Rp2	Rp3	Rp1; Rp2	Rp3
Zimbabwe	Rp2	Rp3	Rp2	Rp3	Y	Rp2	Rp3	Rp1; Rp2	Rp3
Total number of reporting countries (128)	**92**	**82**	**98**	**81**	**116**	**95**	**81**	**99**	**81**
Total number of countries contributing to the four main subject areas	**97**		**126**			**99**		**102**	

Annex 2

Regional distribution of countries

This report follows the regional distribution of countries used by the United Nations Statistics Division in its publications and databases, including for monitoring progress on the Sustainable Development Goals.[4]

NORTHERN AFRICA

Subregion	Country
Northern Africa	Egypt, Libya, Morocco, Sudan, Tunisia

SUB-SAHARAN AFRICA

Subregion	Country
Eastern Africa	Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
Southern Africa	Botswana, Eswatini, Lesotho Namibia, South Africa
Middle Africa	Cameroon, Chad, Congo, Democratic Republic of the Congo
Western Africa	Benin, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Togo

NORTHERN AMERICA

Subregion	Country
Northern America	Canada, United States

LATIN AMERICA AND THE CARIBBEAN

Subregion	Country
Central America	Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
Caribbean	Cuba, Saint Lucia, Trinidad and Tobago
South America	Argentina, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Ecuador, Guyana, Peru, Suriname, Uruguay, Venezuela (Bolivarian Republic of)

[4] See https://unstats.un.org/unsd/methodology/m49/

OCEANIA

Subregion	Country
Melanesia	Papua New Guinea
Polynesia	Cook Islands
Australia and New Zealand	Australia, New Zealand

ASIA

Subregion	Country
Central Asia	Kyrgyzstan, Tajikistan, Uzbekistan
Eastern Asia	China, Japan, Mongolia
South-eastern Asia	Indonesia, Malaysia, Myanmar, Philippines, Thailand, Viet Nam
Southern Asia	Afghanistan, Bangladesh, Bhutan, India, Iran (Islamic Republic of), Nepal, Pakistan, Sri Lanka
Western Asia	Armenia, Azerbaijan, Cyprus, Georgia, Israel, Jordan, Lebanon, Oman, Qatar, Türkiye, Yemen

EUROPE

Subregion	Country
Northern Europe	Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Norway, Sweden, United Kingdom
Eastern Europe	Belarus, Bulgaria, Czechia, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Ukraine
Southern Europe	Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, Serbia, Slovenia, Spain
Western Europe	Austria, Belgium, France, Germany, Netherlands (Kingdom of the), Switzerland

APPENDICES

Appendix 1

Overview of national *ex situ* holdings

Legend

Accessions are categorized by type, expressed as a percentage of the country's total germplasm collections: wild samples; farmers' varieties/landraces; research materials/breeding lines; advanced/improved cultivars.

WS – wild samples
FV/LR – farmers' varieties/landraces
BL – research materials/breeding lines
AC – advanced/improved cultivars
N/D – not defined

The information in this appendix is based on numbers of taxonomic genera, species and accessions of germplasm.

Country	Genera	Species	Accessions	Type of accessions (%)				
	No.	No.	No.	WS	FV/LR	BL	AC	N/D
Afghanistan	11	29	953	0	0	0	0	100
Albania	98	150	4 570	17	44	18	2	19
Argentina	161	270	18 420	9	27	28	20	16
Armenia	120	364	6 458	35	3	7	16	39
Australia	557	2 950	297 198	28	13	37	11	11
Austria	398	733	11 722	5	30	5	44	16
Azerbaijan	451	1 021	13 430	21	13	33	25	8
Bangladesh	355	550	36 119	3	42	41	2	12
Belarus	421	976	27 494	9	3	42	47	-1
Belgium	825	1 983	9 311	17	7	1	6	69
Benin	3	3	483	0	40	0	8	52
Bhutan	4	4	1 162	0	100	0	0	0

(Cont.)

Country	Genera	Species	Accessions	Type of accessions (%)				
	No.	No.	No.	WS	FV/LR	BL	AC	N/D
Bolivia (Plurinational State of)	22	56	11 506	1	99	0	0	0
Bosnia and Herzegovina	88	111	971	25	45	17	0	13
Botswana	20	28	3 044	3	97	0	0	0
Brazil	564	1 746	208 129	2	2	1	14	81
Bulgaria	575	1 696	69 623	3	12	8	5	72
Canada	294	1 059	120 975	23	16	20	25	16
Chile	209	347	47 065	24	47	21	8	0
Colombia	53	169	19 323	1	33	2	13	51
Costa Rica	23	34	3 057	1	41	43	12	3
Croatia	269	391	4 432	46	29	5	19	1
Cuba	376	692	19 786	8	8	59	25	0
Cyprus	250	490	2 541	20	18	0	0	62
Czechia	381	1 054	57 508	10	7	15	60	8
Denmark	11	11	1 043	7	36	0	13	44
Ecuador	387	768	29 469	5	22	17	1	55
Egypt	161	201	14 610	1	43	56	0	0
El Salvador	85	132	1 316	13	56	6	24	1
Eritrea	85	126	4 676	18	81	0	0	1
Estonia	45	78	3 359	7	6	48	39	0
Eswatini	42	53	746	0	98	1	0	1
Ethiopia	201	327	73 164	2	96	0	0	2
Finland	27	54	721	8	57	8	18	9
France	100	340	37 623	10	30	25	11	24
Georgia	40	59	440	1	61	36	0	2
Germany	812	3 427	183 662	15	31	9	31	14
Ghana	288	444	13 064	3	70	18	2	7
Greece	696	1 468	9 570	36	49	5	6	4
Guatemala	6	3	946	0	0	0	0	100
Guinea	9	11	96	4	21	41	34	0
Guyana	94	129	1 294	0	0	0	0	100
Honduras	6	6	64	0	0	50	50	0
Hungary	339	953	49 393	4	22	1	8	65
India	828	1 794	424 812	1	3	1	1	94
Indonesia	5	5	4 902	14	48	7	4	27
Ireland	23	30	1 620	54	12	6	27	1
Israel	680	1 628	27 239	90	0	0	0	10
Italy	185	794	56 988	14	31	16	14	25
Japan	355	989	227 052	11	30	60	0	-1

Country	Genera	Species	Accessions	Type of accessions (%)				
	No.	No.	No.	WS	FV/LR	BL	AC	N/D
Jordan	437	807	4 916	65	32	0	2	1
Kenya	1 013	2 525	51 405	9	25	1	4	61
Kyrgyzstan	70	106	2 638	16	10	0	74	0
Latvia	53	85	2 608	9	1	10	7	73
Lebanon	467	998	2 358	85	14	0	1	0
Lesotho	20	19	3 582	0	0	0	0	100
Libya	313	453	2 345	24	19	44	12	1
Lithuania	133	199	2 246	19	12	39	15	15
Madagascar	35	42	7 829	1	50	36	4	9
Malawi	48	59	3 253	7	88	4	0	1
Malaysia	27	42	13 117	2	52	42	4	0
Mali	6	7	2 473	0	100	0	0	0
Malta	38	53	127	2	97	0	2	-1
Mauritania	8	7	64	5	95	0	0	0
Mexico	559	1 973	78 336	17	43	0	1	39
Mongolia	43	77	19 593	0	12	46	40	2
Montenegro	17	19	388	9	86	0	6	-1
Morocco	158	409	71 783	12	19	59	2	8
Myanmar	32	39	12 050	1	33	2	28	36
Namibia	70	94	2 153	6	94	0	0	0
Nepal	59	99	6 470	2	98	0	0	0
Netherlands (Kingdom of the)	44	298	23 396	16	30	10	35	9
New Zealand	396	1 434	36 144	0	0	0	0	100
Nicaragua	39	51	1 364	2	53	18	27	0
Niger	28	26	4 795	0	98	0	1	1
Nigeria	44	74	7 692	7	93	0	0	0
North Macedonia	55	83	2 158	8	33	17	32	10
Norway	13	25	2 059	0	0	0	0	100
Pakistan	266	442	41 422	1	31	40	5	23
Panama	69	73	824	25	40	23	12	0
Papua New Guinea	35	40	2 940	0	83	16	0	1
Peru	113	226	16 216	8	84	3	1	4
Philippines	220	345	9 912	0	54	5	5	36
Poland	492	1 305	89 944	12	12	23	18	35
Portugal	343	699	69 883	8	68	20	1	3
Qatar	151	204	928	58	0	42	0	0
Republic of Moldova	103	152	6 012	3	11	33	52	1
Romania	224	537	42 363	2	33	31	33	1

(Cont.)

Country	Genera	Species	Accessions	Type of accessions (%)				
	No.	No.	No.	WS	FV/LR	BL	AC	N/D
Russian Federation	216	1 158	200 717	15	23	16	17	29
Senegal	7	9	1 890	0	60	39	1	0
Serbia	5	6	5 588	0	55	44	0	1
Slovakia	142	249	17 164	3	12	24	53	8
Slovenia	124	184	3 008	32	56	2	9	1
South Africa	424	777	6 924	7	68	4	0	21
Spain	746	2 530	78 782	24	56	4	5	11
Sri Lanka	86	123	12 392	1	50	1	32	16
Sudan	92	95	17 168	6	85	2	0	7
Suriname	1	1	83	0	95	5	0	0
Sweden	55	98	448	0	13	1	25	61
Switzerland	83	187	40 037	1	15	3	0	81
Tajikistan	64	88	4 775	3	50	45	2	0
Thailand	91	114	31 887	0	80	19	0	1
Togo	7	10	845	0	90	0	10	0
Trinidad and Tobago	80	104	736	0	62	36	2	0
Tunisia	472	849	24 485	13	50	0	0	37
Türkiye	88	138	38 961	3	92	3	1	1
Uganda	54	91	5 600	10	38	50	0	2
Ukraine	500	1 523	107 675	5	17	30	30	18
United Kingdom	5 884	35 284	847 653	12	1	50	3	34
United Republic of Tanzania	86	133	7 279	2	70	0	0	28
United States	2 532	13 362	584 724	20	14	20	21	25
Uruguay	117	344	18 453	4	6	80	10	0
Uzbekistan	81	191	68 169	1	18	11	18	52
Viet Nam	148	234	26 373	2	82	0	16	0
Zambia	46	71	7 583	1	98	0	0	1
Zimbabwe	38	57	6 231	0	100	0	0	0

Appendix 2

Major germplasm collections by crop and institute

Legend

Collections of germplasm accessions of major crops are grouped by main crop categories (cereals, pseudo-cereals, pulses, roots and tubers, vegetables, fruit plants, nuts, oil plants, forages, sugar crops, fibre plants, spices, stimulant crops and medicinal plants, material plants, ornamental plants). The collections are listed by institutes (indicated by an acronym and the WIEWS institution code) in descending order of the collection size. The percentage of accessions is the percentage of the genus total.

Accessions are categorized by type, expressed as a percentage of the institute's collection: wild species, landraces/ old cultivars, advanced cultivars and breeding lines.

WS: wild species
LR: landraces/old cultivars
BL: research materials/breeding lines
AC: advanced cultivars
OT: (others) the type is unknown

The information in this appendix is based on numbers of accessions or samples of germplasm.

Full names of the institutes mentioned in the following table are given in Appendix 5.

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
CEREALS										
Wheat	*Triticum*	MEX002	CIMMYT	145 039	19	4	36	34	27	0
Wheat	*Triticum*	AUS165	AGG	84 464	11	2	20	60	13	5
Wheat	*Triticum*	USA029	NSGC	63 941	8	4	0	31	58	7
Wheat	*Triticum*	MAR088	INRA CRRAS	47 046	6	0	9	87	1	3
Wheat	*Triticum*	LBN002	ICARDA	39 015	5	5	69	17	0	9
Wheat	*Triticum*	RUS001	VIR	38 175	5	1	41	29	27	1
Wheat	*Triticum*	JPN183	NARO	36 153	5	5	16	79	0	0
Wheat	*Triticum*	IND001	NBPGR	31 825	4	0	3	1	1	95
Wheat	*Triticum*	DEU146	IPK	27 441	4	4	49	12	31	4
Wheat	*Triticum*	CAN004	PGRC	15 457	2	13	6	24	23	33
Wheat	*Triticum*	POL003	IHAR	14 301	2	0	6	49	39	7
Wheat	*Triticum*	ETH085	EBI	13 606	2	0	99	0	0	1
Wheat	*Triticum*	BGR001	IPGR	13 152	2	1	10	9	4	77
Wheat	*Triticum*	CHL028	INIA Intihuasi	12 963	2	0	66	34	0	0
Wheat	*Triticum*	CZE122	CRI	12 843	2	1	9	25	64	1
Wheat	*Triticum*	UKR001	IR	11 070	1	0	4	39	54	4
Wheat	*Triticum*	UZB006	UzRIPI	10 789	1	1	42	16	23	18
Wheat	*Triticum*	GBR247	GRU-JIC	10 349	1	2	23	20	24	31
Wheat	*Triticum*	BRA015	CNPT	9 016	1	6	0	0	56	38
Wheat	*Triticum*	HUN003	NODiK	8 726	1	0	3	0	12	85
Wheat	*Triticum*	MNG030	IPAS	8 182	1	0	16	71	13	0
Wheat	*Triticum*	TUR034	FCCRI	7 871	1	8	80	9	2	0
Wheat	*Triticum*	CHE001	Agroscope Changins	7 450	1	0	25	2	1	72
Wheat	*Triticum*	URY003	INIA LE	7 000	1	0	0	92	8	0
Wheat	*Triticum*	FRA040	INRAe-CLERMONT	6 996	1	0	31	28	40	0
Wheat	*Triticum*	TUN029	BNG	6 341	1	0	100	0	0	0
Wheat	*Triticum*	EGY087	NGB	6 072	1	0	20	80	0	0
Wheat	*Triticum*	Others (119)		88 634	11	7	25	23	24	21
Wheat	***Triticum***	**Total**		**783 917**	**100**	**3**	**27**	**35**	**21**	**13**
Rice	*Oryza*	PHL001	IRRI	132 587	26	4	37	18	2	39
Rice	*Oryza*	IND001	NBPGR	112 593	22	0	5	1	1	93
Rice	*Oryza*	JPN183	NARO	39 996	8	1	54	45	0	0
Rice	*Oryza*	USA970	DB NRRC	36 280	7	0	2	96	2	0
Rice	*Oryza*	THA300	GB-DOA	24 852	5	0	96	3	0	0
Rice	*Oryza*	CIV033	AfricaRice	21 815	4	0	68	1	31	0
Rice	*Oryza*	BRA008	CNPAF	20 932	4	1	0	0	52	47

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Rice	*Oryza*	USA029	NSGC	19 126	4	1	0	28	36	35
Rice	*Oryza*	MYS220	GB, MARDI	12 099	2	0	52	44	4	0
Rice	*Oryza*	BGD002	BRRI	8 705	2	0	64	35	1	0
Rice	*Oryza*	MMR015	MSB	7 591	2	2	49	0	17	32
Rice	*Oryza*	MDG036	FOFIFA DRR	6 932	1	0	56	31	3	10
Rice	*Oryza*	LKA036	PGRC	5 333	1	1	47	0	35	18
Rice	*Oryza*	RUS001	VIR	4 228	1	2	18	50	30	0
Rice	*Oryza*	VNM049	PRC	4 134	1	0	84	0	16	0
Rice	*Oryza*	PHL158	PhilRice	3 795	1	0	89	0	11	0
Rice	*Oryza*	PAK001	PGRP	3 323	1	0	20	37	26	17
Rice	*Oryza*	Others (89)		36 497	7	3	34	32	8	23
Rice	***Oryza***	**Total**		**500 818**	**100**	**2**	**32**	**22**	**8**	**37**
Barley	*Hordeum*	CAN004	PGRC	42 948	11	11	36	26	17	9
Barley	*Hordeum*	AUS165	AGG	39 221	10	1	14	64	17	4
Barley	*Hordeum*	USA029	NSGC	36 597	9	6	0	36	48	9
Barley	*Hordeum*	LBN002	ICARDA	32 482	8	6	58	26	0	9
Barley	*Hordeum*	DEU146	IPK	24 084	6	7	53	11	23	6
Barley	*Hordeum*	BRA003	CENARGEN	18 578	5	0	0	0	0	100
Barley	*Hordeum*	RUS001	VIR	17 788	4	0	0	0	0	100
Barley	*Hordeum*	SWE054	NORDGEN	16 784	4	10	9	74	5	2
Barley	*Hordeum*	ETH085	EBI	16 614	4	0	99	0	0	1
Barley	*Hordeum*	JPN183	NARO	15 820	4	1	12	87	0	0
Barley	*Hordeum*	MEX002	CIMMYT	15 336	4	0	3	86	11	0
Barley	*Hordeum*	GBR247	GRU-JIC	10 441	3	2	18	28	27	25
Barley	*Hordeum*	IND001	NBPGR	8 685	2	0	1	0	0	98
Barley	*Hordeum*	MAR088	INRA CRRAS	8 620	2	1	87	0	2	9
Barley	*Hordeum*	POL003	IHAR	7 432	2	0	3	90	5	3
Barley	*Hordeum*	BGR001	IPGR	6 415	2	0	3	6	7	84
Barley	*Hordeum*	CZE122	CRI	5 364	1	2	7	19	68	4
Barley	*Hordeum*	ARE003	ICBA	5 020	1	4	96	0	0	0
Barley	*Hordeum*	UKR001	IR	4 821	1	0	8	40	49	3
Barley	*Hordeum*	ISR003	ICCI-TELAVUN	4 610	1	100	0	0	0	0
Barley	*Hordeum*	Others (104)		59 302	15	5	33	19	20	23
Barley	***Hordeum***	**Total**		**396 962**	**100**	**5**	**27**	**31**	**15**	**21**
Maize	*Zea*	MEX002	CIMMYT	32 043	14	1	88	8	3	0
Maize	*Zea*	USA020	NC7	19 956	9	2	36	18	43	1
Maize	*Zea*	RUS001	VIR	14 233	6	0	0	0	0	100
Maize	*Zea*	PRT001	BPGV-INIAV	12 097	5	0	22	77	0	1

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Maize	*Zea*	IND001	NBPGR	11 249	5	0	3	5	1	90
Maize	*Zea*	MEX208	CNRG	9 767	4	0	0	0	0	100
Maize	*Zea*	USA174	MGCSC; GSZE	8 506	4	0	0	100	0	0
Maize	*Zea*	UKR001	IR	6 613	3	0	9	76	8	7
Maize	*Zea*	MEX131	UDG-CUCBA	6 110	3	0	100	0	0	0
Maize	*Zea*	JPN183	NARO	5 522	2	0	21	79	0	0
Maize	*Zea*	SRB001	MRIZP	5 475	2	0	55	45	0	0
Maize	*Zea*	ITA386	CREA-CI-BG	5 471	2	0	23	77	0	0
Maize	*Zea*	ROM007	BRGV Suceava	4 922	2	0	73	26	1	0
Maize	*Zea*	BGR001	IPGR	4 828	2	0	24	14	0	61
Maize	*Zea*	PER066	UNA	4 266	2	0	100	0	0	0
Maize	*Zea*	COL017	AGROSAVIA	4 226	2	0	93	7	1	0
Maize	*Zea*	BRA003	CENARGEN	3 679	2	0	75	2	13	10
Maize	*Zea*	MEX006	BANGEV	3 405	1	2	95	0	3	0
Maize	*Zea*	UKR005	IK	3 318	1	0	0	59	0	40
Maize	*Zea*	UZB006	UzRIPI	2 931	1	5	0	24	27	44
Maize	*Zea*	HUN003	NODiK	2 920	1	0	41	8	3	48
Maize	*Zea*	MEX287	BAGENO	2 405	1	0	0	0	0	100
Maize	*Zea*	ECU023	DENAREF	2 345	1	0	39	5	0	56
Maize	*Zea*	NGA039	IITA	2 327	1	0	67	33	0	0
Maize	*Zea*	Others (148)		53 304	23	1	59	19	7	14
Maize	***Zea***	**Total**		**231 918**	**100**	**1**	**45**	**25**	**7**	**23**
Sorghum	*Sorghum*	IND002	ICRISAT	48 260	25	1	89	10	0	0
Sorghum	*Sorghum*	USA016	S9	45 794	24	1	27	13	7	52
Sorghum	*Sorghum*	IND001	NBPGR	26 267	14	0	1	0	0	98
Sorghum	*Sorghum*	ETH085	EBI	10 004	5	0	99	0	0	1
Sorghum	*Sorghum*	SDN002	ARC	7 194	4	2	95	0	0	2
Sorghum	*Sorghum*	AUS165	AGG	7 180	4	7	4	70	4	14
Sorghum	*Sorghum*	KEN212	GeRRI	6 263	3	2	53	0	2	43
Sorghum	*Sorghum*	JPN183	NARO	5 059	3	1	13	86	0	0
Sorghum	*Sorghum*	BRA003	CENARGEN	4 693	2	0	0	0	1	99
Sorghum	*Sorghum*	ARG1348	BGMANFREDI	3 654	2	0	0	87	13	0
Sorghum	*Sorghum*	ZMB030	SPGRC	2 434	1	0	99	0	0	0
Sorghum	*Sorghum*	NGA010	NACGRAB	2 264	1	1	99	0	0	0
Sorghum	*Sorghum*	ZWE049	GRBI	2 077	1	0	100	0	0	0
Sorghum	*Sorghum*	USA995	NCGRP	1 208	1	0	0	27	6	67
Sorghum	*Sorghum*	TZA016	NPGRC	1 163	1	0	35	0	0	65
Sorghum	*Sorghum*	COL017	AGROSAVIA	1 104	1	0	0	0	0	100

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Sorghum	*Sorghum*	BGR001	IPGR	1 046	1	0	3	0	0	97
Sorghum	*Sorghum*	PAK001	PGRP	1 033	1	0	33	49	8	10
Sorghum	*Sorghum*	ZMB048	NPGRC	947	0	0	100	0	0	0
Sorghum	*Sorghum*	Others (101)		12 751	7	3	46	14	9	30
Sorghum	***Sorghum***	**Total**		**190 395**	**100**	**1**	**48**	**14**	**3**	**34**
Oat	*Avena*	CAN004	PGRC	28 514	25	54	5	19	19	3
Oat	*Avena*	USA029	NSGC	20 797	18	48	0	24	20	7
Oat	*Avena*	RUS001	VIR	10 452	9	0	0	0	0	100
Oat	*Avena*	AUS165	AGG	5 095	4	15	3	22	30	30
Oat	*Avena*	DEU146	IPK	4 858	4	14	33	9	39	5
Oat	*Avena*	KEN212	GeRRI	4 197	4	0	0	0	0	100
Oat	*Avena*	GBR016	IBERS-GRU	2 781	2	5	1	90	2	2
Oat	*Avena*	POL003	IHAR	2 676	2	6	9	22	59	4
Oat	*Avena*	BGR001	IPGR	2 672	2	0	1	6	12	80
Oat	*Avena*	GBR247	GRU-JIC	2 640	2	0	17	23	54	6
Oat	*Avena*	MAR088	INRA CRRAS	2 422	2	88	0	12	0	0
Oat	*Avena*	CZE122	CRI	2 204	2	0	5	2	59	34
Oat	*Avena*	ESP004	INIA-CRF	1 709	1	19	75	0	3	3
Oat	*Avena*	ISR003	ICCI-TELAVUN	1 592	1	100	0	0	0	0
Oat	*Avena*	JPN183	NARO	1 444	1	2	6	92	0	0
Oat	*Avena*	MNG030	IPAS	1 429	1	0	4	33	44	18
Oat	*Avena*	IND001	NBPGR	1 395	1	0	0	0	2	97
Oat	*Avena*	HUN003	NODiK	1 343	1	0	6	0	8	85
Oat	*Avena*	SVK003	SVKVIGLAS	1 008	1	0	2	2	94	2
Oat	*Avena*	SWE054	NORDGEN	997	1	2	8	34	36	21
Oat	*Avena*	TUR034	FCCRI	950	1	10	89	0	0	1
Oat	*Avena*	Others (81)		14 421	12	6	21	15	27	32
Oat	***Avena***	**Total**		**115 596**	**100**	**28**	**8**	**18**	**21**	**26**
Pearl millet	*Cenchrus*	IND002	ICRISAT	28 847	49	0	88	11	1	1
Pearl millet	*Cenchrus*	IND001	NBPGR	8 482	14	0	1	2	1	96
Pearl millet	*Cenchrus*	CAN004	PGRC	3 559	6	1	0	0	98	0
Pearl millet	*Cenchrus*	SDN002	ARC	3 187	5	3	72	0	0	25
Pearl millet	*Cenchrus*	NER001	INRAN	2 494	4	0	99	0	1	0
Pearl millet	*Cenchrus*	ZMB030	SPGRC	1 791	3	0	100	0	0	0
Pearl millet	*Cenchrus*	NAM006	NPGRC	1 494	3	0	100	0	0	0
Pearl millet	*Cenchrus*	USA016	S9	1 360	2	5	7	21	36	31
Pearl millet	*Cenchrus*	ZWE049	GRBI	1 031	2	0	100	0	0	0
Pearl millet	*Cenchrus*	NGA010	NACGRAB	1 014	2	2	98	0	0	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Pearl millet	*Cenchrus*	Others (60)		5 856	10	6	57	14	3	20
Pearl millet	***Cenchrus***	**Total**		**59 115**	**100**	**1**	**66**	**7**	**7**	**18**
Wheat	*Triticosecale*	MEX002	CIMMYT	16 871	37	0	0	98	2	0
Wheat	*Triticosecale*	RUS001	VIR	3 997	9	0	0	87	9	4
Wheat	*Triticosecale*	UKR001	IR	3 901	9	0	0	50	17	33
Wheat	*Triticosecale*	POL003	IHAR	2 540	6	0	0	39	11	49
Wheat	*Triticosecale*	USA029	NSGC	2 034	4	0	0	82	17	1
Wheat	*Triticosecale*	DEU146	IPK	1 615	4	0	2	79	19	0
Wheat	*Triticosecale*	AUS165	AGG	1 416	3	1	1	69	25	4
Wheat	*Triticosecale*	Others (59)		13 425	29	3	9	36	19	34
Wheat	***Triticosecale***	**Total**		**45 799**	**100**	**1**	**3**	**69**	**11**	**16**
Wheat	*Aegilops*	ISR003	ICCI-TELAVUN	7 564	20	100	0	0	0	0
Wheat	*Aegilops*	LBN002	ICARDA	5 183	13	88	0	0	0	12
Wheat	*Aegilops*	RUS001	VIR	3 501	9	96	4	0	0	0
Wheat	*Aegilops*	JPN183	NARO	2 432	6	100	0	0	0	0
Wheat	*Aegilops*	USA029	NSGC	2 245	6	100	0	0	0	0
Wheat	*Aegilops*	MEX002	CIMMYT	2 207	6	100	0	0	0	0
Wheat	*Aegilops*	DEU146	IPK	1 517	4	98	0	0	0	2
Wheat	*Aegilops*	IND001	NBPGR	1 450	4	5	0	0	0	95
Wheat	*Aegilops*	AUS165	AGG	1 333	3	88	9	2	0	1
Wheat	*Aegilops*	ARM059	ABSC	1 192	3	99	1	0	0	1
Wheat	*Aegilops*	CZE122	CRI	1 139	3	99	0	0	0	1
Wheat	*Aegilops*	Others (47)		8 722	23	73	3	4	1	19
Wheat	***Aegilops***	Total		**38 485**	**100**	**88**	**1**	**1**	**0**	**10**
Millet	*Panicum*	RUS001	VIR	9 019	24	85	1	10	4	0
Millet	*Panicum*	JPN183	NARO	8 568	22	6	5	89	0	0
Millet	*Panicum*	UKR008	UDS	4 863	13	0	88	2	5	5
Millet	*Panicum*	IND001	NBPGR	3 499	9	0	4	0	2	94
Millet	*Panicum*	KEN212	GeRRI	2 349	6	2	0	0	0	98
Millet	*Panicum*	UKR001	IR	1 498	4	0	45	3	28	24
Millet	*Panicum*	IND002	ICRISAT	1 322	3	0	100	0	0	0
Millet	*Panicum*	USA020	NC7	936	2	1	4	0	4	92
Millet	*Panicum*	USA016	S9	812	2	36	0	1	2	60
Millet	*Panicum*	COL003	CIAT	542	1	98	0	0	1	1
Millet	*Panicum*	Others (77)		4 696	12	14	13	17	15	41
Millet	***Panicum***	**Total**		**38 104**	**100**	**25**	**20**	**25**	**5**	**25**
Millet	*Eleusine*	IND001	NBPGR	12 023	38	0	3	0	1	96
Millet	*Eleusine*	IND002	ICRISAT	7 519	24	3	95	1	2	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Millet	*Eleusine*	KEN212	GeRRI	3 069	10	3	62	1	0	34
Millet	*Eleusine*	ETH085	EBI	1 910	6	0	98	0	0	2
Millet	*Eleusine*	UGA132	PGRC	828	3	17	18	64	0	0
Millet	*Eleusine*	NPL069	NAGRC	800	3	0	100	0	0	0
Millet	*Eleusine*	ZWE049	GRBI	782	2	0	100	0	0	0
Millet	*Eleusine*	USA016	S9	752	2	0	0	0	0	100
Millet	*Eleusine*	Others (39)		4 163	13	5	63	7	2	23
Millet	***Eleusine***	**Total**		**31 846**	**100**	**2**	**49**	**3**	**1**	**45**
Rye	*Secale*	RUS001	VIR	3 203	16	19	36	14	26	5
Rye	*Secale*	POL003	IHAR	2 705	13	2	39	51	7	1
Rye	*Secale*	DEU146	IPK	2 584	13	8	30	24	28	9
Rye	*Secale*	USA029	NSGC	2 097	10	4	0	3	76	18
Rye	*Secale*	CAN004	PGRC	1 461	7	10	17	16	53	4
Rye	*Secale*	BGR001	IPGR	1 326	7	1	3	59	2	34
Rye	*Secale*	Others (73)		6 933	34	7	38	16	28	11
Rye	***Secale***	**Total**		**20 309**	**100**	**8**	**29**	**23**	**30**	**10**
Millet	*Setaria*	IND001	NBPGR	4 821	36	0	4	0	1	95
Millet	*Setaria*	JPN183	NARO	2 414	18	1	61	38	0	0
Millet	*Setaria*	IND002	ICRISAT	1 639	12	9	91	0	0	0
Millet	*Setaria*	USA020	NC7	1 116	8	11	1	2	11	74
Millet	*Setaria*	KEN212	GeRRI	916	7	3	1	0	0	97
Millet	*Setaria*	BGD003	BARI	523	4	0	9	91	0	0
Millet	*Setaria*	AUS165	AGG	308	2	1	35	31	26	7
Millet	*Setaria*	PAK001	PGRP	191	1	1	81	1	0	17
Millet	*Setaria*	Others (60)		1 496	11	26	19	4	8	42
Millet	***Setaria***	**Total**		**13 424**	**100**	**5**	**28**	**12**	**3**	**52**
Tef	*Eragrostis*	ETH085	EBI	4 940	51	0	98	0	0	2
Tef	*Eragrostis*	USA022	W6	1 326	14	45	15	0	4	36
Tef	*Eragrostis*	KEN212	GeRRI	1 072	11	7	0	0	0	93
Tef	*Eragrostis*	ISR002	IGB	378	4	1	0	0	0	99
Tef	*Eragrostis*	ARE003	ICBA	367	4	0	100	0	0	0
Tef	*Eragrostis*	GBR004	RBG	342	4	97	0	0	0	3
Tef	*Eragrostis*	JPN183	NARO	322	3	34	35	31	0	0
Tef	*Eragrostis*	IND001	NBPGR	298	3	0	0	0	0	100
Tef	*Eragrostis*	Others (36)		696	7	48	19	5	3	25
Tef	***Eragrostis***	**Total**		**9 741**	**100**	**15**	**58**	**1**	**1**	**25**
PSEUDO CEREALS										
Amaranth	*Amaranthus*	IND001	NBPGR	6 277	27	1	4	1	0	94

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Amaranth	*Amaranthus*	USA020	NC7	3 341	14	10	8	5	49	28
Amaranth	*Amaranthus*	BRA003	CENARGEN	2 495	11	0	0	0	0	100
Amaranth	*Amaranthus*	TWN001	AVRDC	1 402	6	6	53	0	0	41
Amaranth	*Amaranthus*	MEX208	CNRG	909	4	2	0	0	0	97
Amaranth	*Amaranthus*	Others (102)	9 009	38	12	65	5	3	15	
Amaranth	***Amaranthus***	**Total**		**23 433**	**100**	**7**	**30**	**3**	**8**	**52**
Chenopodium	*Chenopodium*	BOL317	EE-Toralapa INIAF	3 787	33	0	100	0	0	0
Chenopodium	*Chenopodium*	PER014	E.E.A. Illpa-Puno	1 995	17	0	93	0	0	7
Chenopodium	*Chenopodium*	ARE003	ICBA	1 306	11	0	100	0	0	0
Chenopodium	*Chenopodium*	DEU146	IPK	1 028	9	93	1	0	0	5
Chenopodium	*Chenopodium*	ECU023	DENAREF	927	8	1	72	1	2	24
Chenopodium	*Chenopodium*	USA020	NC7	606	5	67	6	0	14	13
Chenopodium	*Chenopodium*	CHL028	INIA Intihuasi	397	3	0	100	0	0	0
Chenopodium	*Chenopodium*	IND001	NBPGR	378	3	3	39	0	2	56
Chenopodium	*Chenopodium*	Others (71)	1 122	10	32	21	20	6	22	
Chenopodium	***Chenopodium***	**Total**		**11 546**	**100**	**15**	**73**	**2**	**2**	**8**
PULSES										
Bean	*Phaseolus*	COL003	CIAT	37 936	20	8	85	0	7	0
Bean	*Phaseolus*	USA022	W6	17 660	9	5	45	3	43	4
Bean	*Phaseolus*	BRA008	CNPAF	17 451	9	0	0	0	0	100
Bean	*Phaseolus*	DEU146	IPK	9 003	5	1	66	4	27	2
Bean	*Phaseolus*	BRA003	CENARGEN	7 892	4	0	0	0	6	94
Bean	*Phaseolus*	MEX208	CNRG	7 501	4	12	0	0	0	88
Bean	*Phaseolus*	RUS001	VIR	6 543	4	0	29	4	28	38
Bean	*Phaseolus*	HUN003	NODiK	4 586	2	0	71	0	0	29
Bean	*Phaseolus*	IND001	NBPGR	4 125	2	0	5	1	1	94
Bean	*Phaseolus*	AUS165	AGG	3 826	2	1	33	41	15	10
Bean	*Phaseolus*	BGR001	IPGR	3 820	2	0	44	0	0	56
Bean	*Phaseolus*	KEN212	GeRRI	3 621	2	0	34	3	35	29
Bean	*Phaseolus*	PRT001	BPGV-INIAV	3 595	2	0	99	0	0	1
Bean	*Phaseolus*	ESP004	INIA-CRF	3 580	2	0	96	0	2	2
Bean	*Phaseolus*	POL003	IHAR	3 365	2	0	58	0	2	40
Bean	*Phaseolus*	ECU023	DENAREF	3 291	2	2	14	15	0	69
Bean	*Phaseolus*	Others (167)		48 953	26	4	64	10	10	12
Bean	***Phaseolus***	**Total**		**186 748**	**100**	**4**	**52**	**4**	**12**	**28**
Chickpea	*Cicer*	IND002	ICRISAT	20 764	21	1	91	6	0	1
Chickpea	*Cicer*	AUS165	AGG	17 083	17	6	17	61	15	2
Chickpea	*Cicer*	LBN002	ICARDA	15 385	16	4	44	38	0	14

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Chickpea	*Cicer*	IND001	NBPGR	14 548	15	0	0	0	0	99
Chickpea	*Cicer*	USA022	W6	7 058	7	7	85	1	7	1
Chickpea	*Cicer*	RUS001	VIR	2 767	3	0	59	20	7	14
Chickpea	*Cicer*	PAK001	PGRP	2 211	2	4	32	58	1	5
Chickpea	*Cicer*	TUR001	AARI	2 060	2	0	100	0	0	0
Chickpea	*Cicer*	UKR001	IR	1 907	2	1	11	60	10	18
Chickpea	*Cicer*	UZB006	UzRIPI	1 731	2	0	0	1	1	98
Chickpea	*Cicer*	ETH085	EBI	1 180	1	0	98	0	0	2
Chickpea	*Cicer*	HUN003	NODiK	1 178	1	0	2	14	0	83
Chickpea	*Cicer*	CHL150	INIA Carillanca	921	1	0	100	0	0	0
Chickpea	*Cicer*	ESP004	INIA-CRF	853	1	0	71	15	2	12
Chickpea	*Cicer*	Others (90)		8 596	9	2	34	27	9	28
Chickpea	***Cicer***	**Total**		**98 242**	**100**	**3**	**46**	**24**	**5**	**23**
Pea	*Lathyrus*	AUS165	AGG	7 575	10	1	36	20	13	30
Pea	*Lathyrus*	USA022	W6	6 319	9	6	48	2	32	13
Pea	*Lathyrus*	DEU146	IPK	5 392	7	1	28	7	57	7
Pea	*Lathyrus*	LBN002	ICARDA	4 594	6	5	29	4	0	62
Pea	*Lathyrus*	IND001	NBPGR	4 527	6	0	2	6	1	91
Pea	*Lathyrus*	GBR247	GRU-JIC	3 562	5	13	17	40	30	0
Pea	*Lathyrus*	GBR165	SASA	3 298	5	0	0	12	60	28
Pea	*Lathyrus*	POL003	IHAR	3 174	4	0	21	36	39	4
Pea	*Lathyrus*	UKR001	IR	2 725	4	0	12	25	59	3
Pea	*Lathyrus*	CZE122	CRI	2 454	3	5	3	14	77	1
Pea	*Lathyrus*	SWE054	NORDGEN	2 414	3	1	20	57	20	2
Pea	*Lathyrus*	GBR016	IBERS-GRU	2 116	3	0	0	95	2	4
Pea	*Lathyrus*	ETH085	EBI	1 886	3	0	95	0	0	5
Pea	*Lathyrus*	BGR001	IPGR	1 749	2	0	1	19	8	72
Pea	*Lathyrus*	ITA436	IBBR	1 716	2	0	0	0	0	100
Pea	*Lathyrus*	PAK001	PGRP	1 605	2	0	10	81	1	7
Pea	*Lathyrus*	ITA394	CREA-ZA-LO	1 225	2	2	43	39	6	10
Pea	*Lathyrus*	HUN003	NODiK	1 221	2	0	7	0	3	89
Pea	*Lathyrus*	Others (118)		15 017	21	2	34	17	21	26
Pea	***Lathyrus***	**Total**		**72 569**	**100**	**2**	**26**	**20**	**25**	**28**
Groundnut	*Arachis*	IND002	ICRISAT	22 056	32	2	51	30	7	10
Groundnut	*Arachis*	IND001	NBPGR	13 819	20	0	0	0	0	99
Groundnut	*Arachis*	USA016	S9	9 948	14	2	3	14	20	62
Groundnut	*Arachis*	BRA003	CENARGEN	3 822	5	11	1	2	1	85
Groundnut	*Arachis*	UZB006	UzRIPI	1 737	2	0	0	2	16	82

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Groundnut	*Arachis*	THA300	GB-DOA	1 732	2	0	0	100	0	0
Groundnut	*Arachis*	RUS001	VIR	1 713	2	0	0	0	0	100
Groundnut	*Arachis*	BGR001	IPGR	1 373	2	0	2	43	5	50
Groundnut	*Arachis*	AUS165	AGG	1 299	2	5	14	60	12	10
Groundnut	*Arachis*	JPN183	NARO	1 147	2	1	36	64	0	0
Groundnut	*Arachis*	BOL317	EE-Toralapa INIAF	1 047	2	0	100	0	0	0
Groundnut	*Arachis*	PAK001	PGRP	774	1	0	0	95	5	0
Groundnut	*Arachis*	SEN002	ISRA-CNRA	749	1	0	0	99	1	0
Groundnut	*Arachis*	MMR015	MSB	655	1	0	7	0	36	58
Groundnut	*Arachis*	ZMB030	SPGRC	606	1	0	98	0	0	2
Groundnut	*Arachis*	Others (73)		7 043	10	4	65	10	5	16
Groundnut	***Arachis***	**Total**		**69 520**	**100**	**2**	**26**	**20**	**7**	**44**
Cowpea	*Vigna*	NGA039	IITA	17 912	30	11	85	4	0	0
Cowpea	*Vigna*	USA016	S9	8 247	14	2	60	0	2	36
Cowpea	*Vigna*	BRA003	CENARGEN	4 928	8	0	0	0	2	98
Cowpea	*Vigna*	IND001	NBPGR	3 953	7	0	5	1	1	93
Cowpea	*Vigna*	JPN183	NARO	3 003	5	14	41	45	0	0
Cowpea	*Vigna*	TWN001	AVRDC	1 896	3	1	86	0	0	14
Cowpea	*Vigna*	RUS001	VIR	1 511	2	0	99	0	0	0
Cowpea	*Vigna*	KEN212	GeRRI	1 228	2	2	29	2	0	67
Cowpea	*Vigna*	LKA036	PGRC	1 166	2	1	81	0	4	14
Cowpea	*Vigna*	BWA015	NPGRC	1 129	2	1	99	0	0	0
Cowpea	*Vigna*	VNM049	PRC	1 109	2	0	99	0	0	0
Cowpea	*Vigna*	ZMB030	SPGRC	1 033	2	0	98	0	0	2
Cowpea	*Vigna*	Others (110)		13 345	22	8	62	8	4	18
Cowpea	***Vigna***	**Total**		**60 460**	**100**	**6**	**62**	**5**	**1**	**25**
Lentil	*Lens*	LBN002	ICARDA	14 377	33	4	31	16	0	48
Lentil	*Lens*	AUS165	AGG	6 217	14	4	49	19	5	24
Lentil	*Lens*	USA022	W6	3 179	7	4	72	2	12	10
Lentil	*Lens*	IND001	NBPGR	2 609	6	0	4	0	1	95
Lentil	*Lens*	RUS001	VIR	2 598	6	0	67	0	0	33
Lentil	*Lens*	CHL150	INIA Carillanca	1 834	4	0	100	0	0	0
Lentil	*Lens*	CAN004	PGRC	1 194	3	1	7	0	3	88
Lentil	*Lens*	UKR001	IR	1 100	3	1	37	27	17	18
Lentil	*Lens*	HUN003	NODiK	1 080	2	0	3	1	0	96
Lentil	*Lens*	TUR001	AARI	925	2	0	100	0	0	0
Lentil	*Lens*	PAK001	PGRP	882	2	7	45	39	1	7
Lentil	*Lens*	Others (67)		7 937	18	5	48	17	8	22

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Lentil	***Lens***	**Total**		**43 932**	**100**	**3**	**44**	**12**	**4**	**37**
Broad bean	*Vicia*	LBN002	ICARDA	9 654	28	0	24	45	0	31
Broad bean	*Vicia*	DEU146	IPK	3 048	9	0	49	34	16	1
Broad bean	*Vicia*	AUS165	AGG	3 035	9	0	42	35	1	21
Broad bean	*Vicia*	GBR016	IBERS-GRU	1 547	4	0	0	84	3	13
Broad bean	*Vicia*	ETH085	EBI	1 427	4	0	94	0	0	6
Broad bean	*Vicia*	ESP004	INIA-CRF	1 328	4	0	90	2	5	2
Broad bean	*Vicia*	RUS001	VIR	1 269	4	0	64	4	32	0
Broad bean	*Vicia*	POL003	IHAR	1 041	3	0	20	3	4	73
Broad bean	*Vicia*	Others (96)		12 234	35	0	48	12	13	26
Broad bean	***Vicia***	**Total**		**34 583**	**100**	**0**	**42**	**27**	**8**	**23**
Pigeon pea	*Cajanus*	IND002	ICRISAT	13 652	46	2	62	36	1	0
Pigeon pea	*Cajanus*	IND001	NBPGR	11 427	38	0	3	0	1	96
Pigeon pea	*Cajanus*	KEN212	GeRRI	1 331	4	0	73	3	3	21
Pigeon pea	*Cajanus*	AUS165	AGG	810	3	32	6	30	1	31
Pigeon pea	*Cajanus*	BRA003	CENARGEN	235	1	0	0	0	0	100
Pigeon pea	*Cajanus*	Others (67)		2 279	8	11	64	5	3	17
Pigeon pea	***Cajanus***	**Total**		**29 734**	**100**	**3**	**38**	**18**	**1**	**41**
Lupin	*Lupinus*	AUS165	AGG	3 527	14	0	2	1	0	96
Lupin	*Lupinus*	DEU146	IPK	2 762	11	15	42	8	14	20
Lupin	*Lupinus*	RUS001	VIR	2 735	11	17	22	37	20	3
Lupin	*Lupinus*	ESP010	SIAEX	2 068	8	57	35	1	3	3
Lupin	*Lupinus*	USA022	W6	1 597	6	44	40	1	8	7
Lupin	*Lupinus*	CHL150	INIA Carillanca	1 427	6	0	0	100	0	0
Lupin	*Lupinus*	PRT001	BPGV-INIAV	1 337	5	50	43	5	0	1
Lupin	*Lupinus*	POL003	IHAR	1 292	5	2	2	4	11	81
Lupin	*Lupinus*	PER029	INIA-EEA.SA.	1 057	4	0	100	0	0	0
Lupin	*Lupinus*	UKR004	IZ	853	3	0	9	17	6	68
Lupin	*Lupinus*	Others (82)		7 049	27	17	25	20	13	25
Lupin	***Lupinus***	**Total**		**25 704**	**100**	**18**	**26**	**17**	**9**	**30**
Bambara groundnut	*Vigna*	NGA039	IITA	2 030	38	2	89	0	3	6
Bambara groundnut	*Vigna*	BWA015	NPGRC	437	8	0	100	0	0	0
Bambara groundnut	*Vigna*	GHA091	PGRRI	412	8	0	89	9	2	0
Bambara groundnut	*Vigna*	ZMB030	SPGRC	342	6	0	98	0	0	2
Bambara groundnut	*Vigna*	ZMB048	NPGRC	288	5	0	100	0	0	0
Bambara groundnut	*Vigna*	TZA016	NPGRC	284	5	0	87	0	0	12
Bambara groundnut	*Vigna*	NER001	INRAN	230	4	0	100	0	0	0
Bambara groundnut	*Vigna*	NGA010	NACGRAB	223	4	8	92	0	0	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Bambara groundnut	*Vigna*	ZAF062	DALRRD	192	4	0	99	0	0	1
Bambara groundnut	*Vigna*	ZWE049	GRBI	155	3	0	100	0	0	0
Bambara groundnut	*Vigna*	Others (16)		712	13	8	65	6	3	18
Bambara groundnut	***Vigna***	**Total**		**5 305**	**100**	**2**	**89**	**2**	**2**	**5**
Winged bean	*Psophocarpus*	TWN001	AVRDC	285	18	4	96	0	0	0
Winged bean	*Psophocarpus*	IND001	NBPGR	226	14	0	1	0	1	97
Winged bean	*Psophocarpus*	NGA039	IITA	193	12	0	100	0	0	0
Winged bean	*Psophocarpus*	USA016	S9	178	11	0	3	0	1	97
Winged bean	*Psophocarpus*	AUS165	AGG	176	11	0	88	9	0	3
Winged bean	*Psophocarpus*	VNM049	PRC	165	10	0	99	0	1	0
Winged bean	*Psophocarpus*	JPN183	NARO	106	7	0	59	41	0	0
Winged bean	*Psophocarpus*	Others (20)		278	17	23	36	1	6	33
Winged bean	***Psophocarpus***	**Total**		**1 607**	**100**	**5**	**59**	**4**	**1**	**31**
ROOTS AND TUBERS										
Potato	*Solanum*	PER001	CIP	8 390	14	33	57	1	9	1
Potato	*Solanum*	DEU159	IPK	6 244	11	22	35	9	29	5
Potato	*Solanum*	RUS001	VIR	5 833	10	44	56	0	0	0
Potato	*Solanum*	USA004	NR6	5 769	10	69	18	6	7	0
Potato	*Solanum*	COL017	AGROSAVIA	2 914	5	3	48	0	1	48
Potato	*Solanum*	CZE027	HBROD	2 694	5	5	1	33	50	10
Potato	*Solanum*	UKR026	IKA	2 300	4	20	1	38	17	24
Potato	*Solanum*	JPN183	NARO	1 894	3	4	1	95	0	0
Potato	*Solanum*	ARG1347	BAL	1 649	3	64	25	6	5	0
Potato	*Solanum*	BLR016	RPC-PFVG	1 573	3	37	0	9	54	0
Potato	*Solanum*	BOL317	EE-Toralapa INIAF	1 569	3	0	100	0	0	0
Potato	*Solanum*	NLD037	CGN	1 508	3	85	14	0	0	0
Potato	*Solanum*	GBR251	JHI	1 502	3	45	23	0	0	33
Potato	*Solanum*	POL002	IPRBON	1 427	2	0	0	0	100	0
Potato	*Solanum*	PER867	Asociación ANDES	1 195	2	0	66	34	0	0
Potato	*Solanum*	ECU023	DENAREF	1 079	2	7	14	0	0	79
Potato	*Solanum*	MEX208	CNRG	833	1	1	0	0	12	87
Potato	*Solanum*	CHL071	UACH	809	1	11	89	0	0	0
Potato	*Solanum*	EST019	ETKI	802	1	0	9	53	37	0
Potato	*Solanum*	CUB005	INCA	744	1	9	0	78	13	0
Potato	*Solanum*	ROM018	INCDCSZ Brasov	719	1	2	0	0	98	0
Potato	*Solanum*	Others (73)		6 476	11	11	23	14	29	23
Potato	***Solanum***	**Total**		**57 923**	**100**	**28**	**32**	**12**	**18**	**11**
Sweet potato	*Ipomoea*	PER001	CIP	6 281	33	17	68	10	4	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Sweet potato	*Ipomoea*	JPN183	NARO	3 505	18	5	29	67	0	0
Sweet potato	*Ipomoea*	USA016	S9	1 214	6	17	10	9	33	30
Sweet potato	*Ipomoea*	BRA012	CNPH	1 070	6	0	0	2	0	98
Sweet potato	*Ipomoea*	CUB006	INIVIT	920	5	13	5	77	6	0
Sweet potato	*Ipomoea*	ECU023	DENAREF	876	5	28	63	0	0	9
Sweet potato	*Ipomoea*	PNG039	NARI-HRC	855	4	0	100	0	0	0
Sweet potato	*Ipomoea*	VNM049	PRC	719	4	0	72	0	27	0
Sweet potato	*Ipomoea*	FJI049	CePaCT	363	2	0	100	0	0	0
Sweet potato	*Ipomoea*	ARG1342	BBC-INTA	324	2	0	2	0	3	95
Sweet potato	*Ipomoea*	PRT102	ISOPlexis	321	2	0	98	2	0	0
Sweet potato	*Ipomoea*	Others (68)		2 723	14	11	51	11	3	23
Sweet potato	***Ipomoea***	**Total**		**19 171**	**100**	**11**	**49**	**21**	**5**	**13**
Cassava	*Manihot*	COL003	CIAT	5 963	34	6	83	11	0	0
Cassava	*Manihot*	NGA039	IITA	3 184	18	0	49	44	0	7
Cassava	*Manihot*	BRA004	CNPMF	2 296	13	0	6	0	0	94
Cassava	*Manihot*	PER034	INIA-EEA.DONOSO	740	4	0	100	0	0	0
Cassava	*Manihot*	CUB006	INIVIT	630	4	0	0	97	3	0
Cassava	*Manihot*	BRA027	CPAA	421	2	0	59	4	0	37
Cassava	*Manihot*	GHA091	PGRRI	419	2	0	80	0	5	15
Cassava	*Manihot*	TGO031	CRA-L	383	2	0	84	0	16	0
Cassava	*Manihot*	PHL129	IPB-NPGRL	365	2	0	0	0	0	100
Cassava	*Manihot*	MWI041	MPGRC	330	2	0	98	2	0	0
Cassava	*Manihot*	ECU023	DENAREF	326	2	0	2	0	0	98
Cassava	*Manihot*	Others (47)		2 625	15	3	42	11	5	39
Cassava	***Manihot***	**Total**		**17 682**	**100**	**3**	**55**	**17**	**1**	**24**
Yam	*Dioscorea*	NGA039	IITA	5 931	57	7	86	1	0	6
Yam	*Dioscorea*	GHA091	PGRRI	1 167	11	0	99	0	0	0
Yam	*Dioscorea*	FRA109	INRAe-ANTILLE	481	5	0	88	0	4	9
Yam	*Dioscorea*	VNM049	PRC	360	3	1	98	0	0	0
Yam	*Dioscorea*	FJI049	CePaCT	356	3	0	100	0	0	0
Yam	*Dioscorea*	CUB006	INIVIT	241	2	0	0	94	6	0
Yam	*Dioscorea*	Others (57)		1 836	18	29	51	4	0	16
Yam	***Dioscorea***	**Total**		**10 372**	**100**	**9**	**80**	**4**	**0**	**7**
Taro	*Colocasia*	FJI049	CePaCT	1 303	31	0	78	22	0	0
Taro	*Colocasia*	VNM049	PRC	1 232	30	1	96	0	3	0
Taro	*Colocasia*	GHA091	PGRRI	272	7	0	98	0	1	0
Taro	*Colocasia*	JPN183	NARO	240	6	14	80	6	0	0
Taro	*Colocasia*	PNG041	MRC Bubia	213	5	0	100	0	0	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Taro	*Colocasia*	ETH085	EBI	138	3	0	100	0	0	0
Taro	*Colocasia*	CUB006	INIVIT	132	3	0	0	94	6	0
Taro	*Colocasia*	MWI041	MPGRC	111	3	0	100	0	0	0
Taro	*Colocasia*	PHL129	IPB-NPGRL	110	3	0	0	0	0	100
Taro	*Colocasia*	MYS220	GB, MARDI	78	2	0	100	0	0	0
Taro	*Colocasia*	PNG004	SRC Laloki	67	2	0	100	0	0	0
Taro	*Colocasia*	PRT102	ISOPlexis	67	2	0	52	48	0	0
Taro	*Colocasia*	Others (20)		206	5	1	65	15	0	19
Taro	***Colocasia***	**Total**		**4 169**	**100**	**1**	**82**	**12**	**1**	**4**
VEGETABLES										
Tomato	*Solanum*	TWN001	AVRDC	9 759	14	9	80	4	0	6
Tomato	*Solanum*	USA003	NE9	6 610	9	10	6	2	11	71
Tomato	*Solanum*	DEU146	IPK	4 645	7	2	35	22	35	7
Tomato	*Solanum*	USA176	GSLY	3 925	6	27	0	23	1	48
Tomato	*Solanum*	ESP026	BGUPV	3 181	4	8	67	0	4	20
Tomato	*Solanum*	IND001	NBPGR	2 911	4	1	5	2	1	90
Tomato	*Solanum*	JPN183	NARO	2 595	4	4	22	74	0	0
Tomato	*Solanum*	CAN004	PGRC	2 574	4	1	0	23	58	18
Tomato	*Solanum*	HUN003	NODiK	1 999	3	1	23	0	2	75
Tomato	*Solanum*	BRA012	CNPH	1 778	3	0	0	0	0	100
Tomato	*Solanum*	ESP027	CITA-HOR	1 711	2	0	85	0	4	10
Tomato	*Solanum*	ARG1350	BGLACONSULTA	1 711	2	0	5	51	44	0
Tomato	*Solanum*	BRA003	CENARGEN	1 622	2	0	0	0	23	77
Tomato	*Solanum*	POL003	IHAR	1 560	2	0	31	3	19	47
Tomato	*Solanum*	UKR021	IOB	1 523	2	0	5	23	63	9
Tomato	*Solanum*	BGR001	IPGR	1 479	2	0	26	13	3	58
Tomato	*Solanum*	CZE122	CRI	1 431	2	4	7	3	84	2
Tomato	*Solanum*	NLD037	CGN	1 421	2	8	13	13	57	8
Tomato	*Solanum*	AUS165	AGG	1 276	2	8	0	12	69	12
Tomato	*Solanum*	GHA091	PGRRI	1 025	1	0	88	11	0	0
Tomato	*Solanum*	Others (146)		16 325	23	6	38	17	14	24
Tomato	***Solanum***	**Total**		**71 061**	**100**	**6**	**33**	**14**	**17**	**31**
Capsicum	*Capsicum*	TWN001	AVRDC	8 548	17	1	87	0	0	12
Capsicum	*Capsicum*	USA016	S9	4 965	10	1	7	0	19	72
Capsicum	*Capsicum*	IND001	NBPGR	4 607	9	0	4	1	1	93
Capsicum	*Capsicum*	JPN183	NARO	3 066	6	2	38	61	0	0
Capsicum	*Capsicum*	BGR001	IPGR	1 925	4	0	73	2	4	20
Capsicum	*Capsicum*	DEU146	IPK	1 534	3	2	66	4	28	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Capsicum	*Capsicum*	BRA012	CNPH	1 370	3	0	0	1	1	97
Capsicum	*Capsicum*	TUR001	AARI	1 318	3	0	100	0	0	0
Capsicum	*Capsicum*	HUN003	NODiK	1 192	2	0	44	1	7	49
Capsicum	*Capsicum*	NLD037	CGN	1 177	2	5	30	2	44	19
Capsicum	*Capsicum*	MEX006	BANGEV	1 154	2	0	100	0	0	0
Capsicum	*Capsicum*	MEX208	CNRG	1 052	2	0	0	0	0	100
Capsicum	*Capsicum*	CRI085	CATIE	878	2	0	100	0	0	0
Capsicum	*Capsicum*	GHA091	PGRRI	856	2	0	71	13	0	16
Capsicum	*Capsicum*	ESP026	BGUPV	852	2	1	85	0	2	12
Capsicum	*Capsicum*	VNM049	PRC	771	2	0	64	0	36	0
Capsicum	*Capsicum*	BRA003	CENARGEN	702	1	0	3	0	1	96
Capsicum	*Capsicum*	Others (127)		14 975	29	1	56	10	11	22
Capsicum	***Capsicum***	**Total**		**50 942**	**100**	**1**	**51**	**7**	**8**	**33**
Cantaloupe	*Cucumis*	JPN183	NARO	5 170	14	6	39	55	0	0
Cantaloupe	*Cucumis*	USA020	NC7	4 947	14	8	11	1	76	3
Cantaloupe	*Cucumis*	IND001	NBPGR	2 368	7	8	4	1	1	86
Cantaloupe	*Cucumis*	FRA011	INRAe-AVIGNON	2 131	6	0	3	1	1	95
Cantaloupe	*Cucumis*	BGR001	IPGR	1 510	4	0	19	4	1	76
Cantaloupe	*Cucumis*	UZB006	UzRIPI	1 314	4	0	5	0	15	80
Cantaloupe	*Cucumis*	DEU146	IPK	1 194	3	1	38	3	52	7
Cantaloupe	*Cucumis*	NLD037	CGN	1 003	3	0	18	2	39	41
Cantaloupe	*Cucumis*	BGD206	LTS	988	3	0	0	100	0	0
Cantaloupe	*Cucumis*	ESP026	BGUPV	943	3	2	95	0	0	2
Cantaloupe	*Cucumis*	CZE122	CRI	939	3	3	3	2	7	84
Cantaloupe	*Cucumis*	Others (128)		13 465	37	4	52	11	10	23
Cantaloupe	***Cucumis***	**Total**		**35 972**	**100**	**4**	**32**	**15**	**18**	**30**
Cucurbita	*Cucurbita*	BRA012	CNPH	2 923	9	0	0	0	1	99
Cucurbita	*Cucurbita*	CRI085	CATIE	2 114	6	0	100	0	0	0
Cucurbita	*Cucurbita*	TWN001	AVRDC	1 531	4	1	85	0	0	14
Cucurbita	*Cucurbita*	BRA003	CENARGEN	1 365	4	0	25	0	6	69
Cucurbita	*Cucurbita*	USA016	S9	1 348	4	13	32	0	14	41
Cucurbita	*Cucurbita*	VNM049	PRC	1 231	4	0	99	0	1	0
Cucurbita	*Cucurbita*	UZB006	UzRIPI	1 182	3	0	0	0	15	84
Cucurbita	*Cucurbita*	JPN183	NARO	1 146	3	10	63	27	0	0
Cucurbita	*Cucurbita*	BRA017	CPATSA	1 124	3	0	0	0	0	100
Cucurbita	*Cucurbita*	HUN003	NODiK	1 088	3	0	49	0	4	47
Cucurbita	*Cucurbita*	DEU146	IPK	1 053	3	0	52	2	31	14
Cucurbita	*Cucurbita*	Others (140)		18 157	53	2	63	3	10	22

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cucurbita	***Cucurbita***	**Total**		**34 262**	**100**	**2**	**55**	**3**	**8**	**33**
Allium	*Allium*	DEU146	IPK	2 541	11	50	29	5	9	7
Allium	*Allium*	GBR006	HRIGRU	1 822	8	6	13	1	77	2
Allium	*Allium*	USA022	W6	1 267	5	46	22	0	12	21
Allium	*Allium*	JPN183	NARO	1 230	5	12	23	64	0	0
Allium	*Allium*	POL101	InHort	1 196	5	10	59	1	5	26
Allium	*Allium*	USA003	NE9	1 195	5	0	19	2	15	63
Allium	*Allium*	IND001	NBPGR	1 162	5	1	1	0	1	97
Allium	*Allium*	Others (155)		13 167	56	9	50	6	12	22
Allium	***Allium***	**Total**		**23 580**	**100**	**15**	**39**	**8**	**15**	**23**
Rape	*Brassica*	IND001	NBPGR	4 728	25	0	1	0	0	98
Rape	*Brassica*	AUS165	AGG	2 647	14	0	5	1	2	93
Rape	*Brassica*	PAK001	PGRP	1 588	8	0	31	53	2	14
Rape	*Brassica*	JPN183	NARO	1 587	8	1	17	83	0	0
Rape	*Brassica*	TWN001	AVRDC	1 049	6	0	99	1	0	0
Rape	*Brassica*	CAN004	PGRC	784	4	1	13	47	37	2
Rape	*Brassica*	GBR006	HRIGRU	701	4	1	28	0	67	4
Rape	*Brassica*	USA020	NC7	675	4	2	5	0	4	89
Rape	*Brassica*	DEU146	IPK	539	3	1	24	5	53	18
Rape	*Brassica*	EST019	ETKI	512	3	0	0	99	1	0
Rape	*Brassica*	Others (82)		3 942	21	4	31	7	27	30
Rape	***Brassica***	**Total**		**18 752**	**100**	**1**	**20**	**18**	**12**	**49**
Eggplant	*Solanum*	IND001	NBPGR	4 416	25	2	1	0	1	95
Eggplant	*Solanum*	TWN001	AVRDC	3 609	20	85	10	0	0	6
Eggplant	*Solanum*	JPN183	NARO	1 517	8	2	54	43	0	0
Eggplant	*Solanum*	USA016	S9	820	5	1	2	0	3	94
Eggplant	*Solanum*	GHA091	PGRRI	481	3	9	81	10	0	0
Eggplant	*Solanum*	VNM049	PRC	463	3	3	78	0	19	0
Eggplant	*Solanum*	NLD037	CGN	429	2	4	56	2	21	16
Eggplant	*Solanum*	Others (123)		6 120	34	13	38	11	8	30
Eggplant	***Solanum***	**Total**		**17 855**	**100**	**23**	**25**	**8**	**4**	**40**
Oleracea	*Brassica*	GBR006	HRIGRU	3 965	23	1	13	1	84	1
Oleracea	*Brassica*	USA003	NE9	1 595	9	0	0	0	12	88
Oleracea	*Brassica*	DEU146	IPK	1 312	8	2	30	6	61	2
Oleracea	*Brassica*	FRA010	INRAe-RENNES	767	4	0	100	0	0	0
Oleracea	*Brassica*	PRT001	BPGV-INIAV	750	4	0	99	1	0	0
Oleracea	*Brassica*	BGR001	IPGR	736	4	0	7	6	26	61
Oleracea	*Brassica*	JPN183	NARO	690	4	0	20	80	0	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Oleracea	*Brassica*	NLD037	CGN	642	4	1	14	2	78	5
Oleracea	*Brassica*	Others (103)		7 003	40	2	32	19	21	26
Oleracea	***Brassica***	**Total**		**17 460**	**100**	**1**	**28**	**12**	**37**	**22**
Lettuce	*Lactuca*	USA022	W6	2 672	16	28	23	2	41	5
Lettuce	*Lactuca*	NLD037	CGN	2 561	16	41	7	1	47	4
Lettuce	*Lactuca*	GBR006	HRIGRU	1 504	9	12	7	0	78	2
Lettuce	*Lactuca*	CZE122	CRI	1 420	9	40	4	2	54	1
Lettuce	*Lactuca*	DEU146	IPK	1 155	7	8	44	1	45	2
Lettuce	*Lactuca*	BGR001	IPGR	984	6	0	9	7	6	78
Lettuce	*Lactuca*	ESP027	CITA-HOR	851	5	1	86	0	10	2
Lettuce	*Lactuca*	HUN003	NODiK	551	3	1	58	0	1	40
Lettuce	*Lactuca*	Others (83)		4 600	28	15	37	11	23	13
Lettuce	***Lactuca***	**Total**		**16 298**	**100**	**21**	**26**	**4**	**37**	**12**
Okra	*Abelmoschus*	IND001	NBPGR	3 581	26	4	4	1	0	90
Okra	*Abelmoschus*	USA016	S9	3 005	21	0	10	0	1	89
Okra	*Abelmoschus*	TWN001	AVRDC	2 078	15	0	77	0	0	23
Okra	*Abelmoschus*	GHA091	PGRRI	746	5	0	64	2	1	33
Okra	*Abelmoschus*	SDN002	ARC	683	5	13	85	0	0	2
Okra	*Abelmoschus*	TUR001	AARI	626	4	0	100	0	0	0
Okra	*Abelmoschus*	Others (84)		3 309	24	1	68	6	3	23
Okra	***Abelmoschus***	**Total**		**14 028**	**100**	**2**	**42**	**2**	**1**	**53**
Melon	*Citrullus*	USA016	S9	1 895	16	11	13	1	16	60
Melon	*Citrullus*	BRA017	CPATSA	995	8	0	0	0	0	100
Melon	*Citrullus*	UZB006	UzRIPI	941	8	0	0	13	14	72
Melon	*Citrullus*	JPN183	NARO	807	7	24	18	58	0	0
Melon	*Citrullus*	BRA012	CNPH	644	5	0	0	0	0	100
Melon	*Citrullus*	ZAF062	DALRRD	531	4	0	91	0	0	8
Melon	*Citrullus*	SDN002	ARC	510	4	10	88	0	0	2
Melon	*Citrullus*	IND001	NBPGR	462	4	1	0	1	0	98
Melon	*Citrullus*	ZWE049	GRBI	357	3	0	100	0	0	0
Melon	*Citrullus*	Others (93)		4 860	40	4	57	6	15	19
Melon	***Citrullus***	**Total**		**12 002**	**100**	**5**	**37**	**7**	**10**	**41**
Carrot	*Daucus*	USA020	NC7	1 563	19	52	3	1	35	9
Carrot	*Daucus*	GBR006	HRIGRU	1 497	18	14	18	2	65	1
Carrot	*Daucus*	POL003	IHAR	657	8	43	25	8	11	13
Carrot	*Daucus*	DEU146	IPK	492	6	33	16	1	49	1
Carrot	*Daucus*	CZE122	CRI	404	5	9	1	1	86	4
Carrot	*Daucus*	JPN183	NARO	309	4	0	11	89	0	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Carrot	*Daucus*	PAK001	PGRP	264	3	0	37	0	1	62
Carrot	*Daucus*	Others (93)		3 259	39	36	20	5	13	27
Carrot	***Daucus***	**Total**		**8 445**	**100**	**32**	**16**	**6**	**31**	**15**
Radish	*Raphanus*	JPN183	NARO	964	12	1	32	66	0	0
Radish	*Raphanus*	GBR006	HRIGRU	802	10	1	14	0	82	3
Radish	*Raphanus*	DEU146	IPK	766	10	23	35	1	39	2
Radish	*Raphanus*	USA003	NE9	717	9	1	4	0	18	78
Radish	*Raphanus*	GBR165	SASA	556	7	0	0	0	100	0
Radish	*Raphanus*	BGD206	LTS	408	5	0	0	100	0	0
Radish	*Raphanus*	PAK001	PGRP	332	4	0	52	3	8	37
Radish	*Raphanus*	IND001	NBPGR	326	4	0	4	7	4	85
Radish	*Raphanus*	Others (89)		3 022	38	7	34	8	25	26
Radish	***Raphanus***	**Total**		**7 893**	**100**	**5**	**24**	**17**	**31**	**23**
FRUIT PLANTS										
Grape	*Vitis*	PRT018	ISA	25 571	30	0	100	0	0	0
Grape	*Vitis*	FRA139	INRAe-VASSAL	7 832	9	2	49	30	0	19
Grape	*Vitis*	USA028	DAV	3 618	4	13	33	23	7	24
Grape	*Vitis*	ESP080	IMIDRA	3 530	4	19	46	35	1	0
Grape	*Vitis*	UKR050	IVM	3 327	4	1	39	16	20	24
Grape	*Vitis*	CHE019	Agroscope Pully	3 254	4	0	0	0	0	100
Grape	*Vitis*	ITA388	CREA-VE-CON	3 040	4	0	46	11	2	41
Grape	*Vitis*	DEU098	JKI	2 849	3	3	23	32	27	14
Grape	*Vitis*	FRA038	INRAe-COLMAR	2 383	3	1	36	39	0	23
Grape	*Vitis*	MDA004	LGGRB	1 909	2	2	0	16	82	0
Grape	*Vitis*	BRA141	CNPUV	1 761	2	4	0	46	50	0
Grape	*Vitis*	CHE109	LZSG	1 560	2	0	0	0	0	100
Grape	*Vitis*	UZB006	UzRIPI	1 523	2	3	87	9	0	1
Grape	*Vitis*	Others (99)		23 729	28	4	35	12	25	23
Grape	***Vitis***	**Total**		**85 886**	**100**	**3**	**54**	**13**	**12**	**18**
Apple	*Malus*	USA167	GEN	6 072	12	56	0	0	2	42
Apple	*Malus*	RUS001	VIR	3 397	7	8	1	7	84	0
Apple	*Malus*	CHE063	PSR	2 395	5	0	0	0	0	100
Apple	*Malus*	GBR030	NFC	2 247	4	0	0	0	0	100
Apple	*Malus*	JPN183	NARO	1 925	4	26	4	71	0	0
Apple	*Malus*	CHE090	OSS Roggwil	1 874	4	0	4	0	0	96
Apple	*Malus*	PRT102	ISOPlexis	1 830	4	0	100	0	0	0
Apple	*Malus*	BLR017	IFG	1 544	3	2	3	61	34	0
Apple	*Malus*	AUT024	KLOST	1 390	3	0	9	0	91	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Apple	*Malus*	POL103	AiZFwB	1 374	3	0	0	0	34	66
Apple	*Malus*	CZE031	HOLOVOU	1 195	2	2	14	35	44	6
Apple	*Malus*	ITA378	CREA-OFA-RM	1 090	2	2	57	7	19	16
Apple	*Malus*	Others (139)		24 613	48	1	26	3	22	47
Apple	***Malus***	**Total**		**50 946**	**100**	**9**	**19**	**7**	**22**	**43**
Prunus	*Prunus*	RUS001	VIR	2 971	8	37	7	7	43	6
Prunus	*Prunus*	ITA378	CREA-OFA-RM	2 324	6	0	34	5	51	10
Prunus	*Prunus*	USA028	DAV	1 681	4	23	7	14	31	25
Prunus	*Prunus*	UKR036	NBS	1 618	4	1	3	12	66	17
Prunus	*Prunus*	UZB006	UzRIPI	1 414	4	0	83	1	8	8
Prunus	*Prunus*	BLR017	IFG	1 197	3	1	8	31	61	0
Prunus	*Prunus*	JPN183	NARO	1 142	3	3	26	71	0	0
Prunus	*Prunus*	CHE065	FRUCTUS	1 025	3	0	3	0	0	97
Prunus	*Prunus*	CHE066	RP	974	3	0	0	0	0	100
Prunus	*Prunus*	ROM009	ICDP Pitesti	890	2	0	25	21	54	0
Prunus	*Prunus*	ROM035	SCDP Constanta	887	2	0	2	28	70	0
Prunus	*Prunus*	UKR046	KPS	844	2	1	11	3	45	40
Prunus	*Prunus*	SVK001	SVKPIEST	807	2	0	6	27	59	8
Prunus	*Prunus*	AUT024	KLOST	794	2	0	20	0	80	0
Prunus	*Prunus*	Others (159)		18 842	50	5	27	5	26	37
Prunus	***Prunus***	**Total**		**37 410**	**100**	**7**	**22**	**10**	**33**	**28**
Pear	*Pyrus*	USA026	COR	2 370	11	16	4	26	51	4
Pear	*Pyrus*	CHE090	OSS Roggwil	1 572	7	0	13	0	0	87
Pear	*Pyrus*	RUS001	VIR	1 478	7	17	26	7	50	0
Pear	*Pyrus*	CHE063	PSR	1 444	7	0	0	0	0	100
Pear	*Pyrus*	CHE066	RP	1 243	6	0	0	0	0	100
Pear	*Pyrus*	ITA378	CREA-OFA-RM	812	4	2	47	8	26	16
Pear	*Pyrus*	JPN183	NARO	781	4	31	14	55	0	0
Pear	*Pyrus*	UKR046	KPS	760	4	2	5	1	22	70
Pear	*Pyrus*	BLR017	IFG	726	3	3	12	40	44	0
Pear	*Pyrus*	POL103	AiZFwB	632	3	0	0	0	20	80
Pear	*Pyrus*	Others (115)		9 215	44	3	39	4	16	39
Pear	***Pyrus***	**Total**		**21 033**	**100**	**6**	**23**	**9**	**20**	**42**
Strawberry	*Fragaria*	CAN025	CCGB	2 013	25	53	0	0	7	40
Strawberry	*Fragaria*	USA026	COR	1 985	24	63	1	10	25	0
Strawberry	*Fragaria*	RUS001	VIR	726	9	11	5	3	81	0
Strawberry	*Fragaria*	JPN183	NARO	572	7	13	5	82	0	0
Strawberry	*Fragaria*	CHE063	PSR	559	7	0	0	0	0	100

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Strawberry	*Fragaria*	DEU451	JKI	467	6	0	0	0	0	100
Strawberry	*Fragaria*	BLR017	IFG	181	2	1	0	25	73	0
Strawberry	*Fragaria*	ITA380	CREA-OFA-FC	175	2	0	0	0	99	1
Strawberry	*Fragaria*	ESP138	IFAPACHU	164	2	21	1	0	0	78
Strawberry	*Fragaria*	Others (53)		1 335	16	7	4	16	31	41
Strawberry	***Fragaria***	**Total**		**8 177**	**100**	**32**	**2**	**12**	**24**	**31**
Citrus	*Citrus*	USA129	RIV NCGRCD	1 569	20	2	5	2	64	26
Citrus	*Citrus*	JPN183	NARO	1 491	19	3	41	57	0	0
Citrus	*Citrus*	FRA064	INRAe-CORSE	777	10	0	0	15	0	85
Citrus	*Citrus*	BRA004	CNPMF	705	9	0	0	13	80	7
Citrus	*Citrus*	ITA226	CREA-OFA-ACI	591	7	4	70	13	13	0
Citrus	*Citrus*	ESP025	IVIA	425	5	0	0	0	0	100
Citrus	*Citrus*	Others (57)		2 416	30	2	36	6	41	15
Citrus	***Citrus***	**Total**		**7 974**	**100**	**2**	**25**	**16**	**33**	**24**
Banana	*Musa*	BEL084	ITC	1 689	26	13	76	0	10	0
Banana	*Musa*	PHL024	BPI-DNCRDC	473	7	0	33	65	2	0
Banana	*Musa*	NGA039	IITA	393	6	0	0	40	0	60
Banana	*Musa*	CUB006	INIVIT	367	6	0	0	100	0	0
Banana	*Musa*	FRA201	CIRAD-FLHOR	365	6	0	0	0	0	100
Banana	*Musa*	SDN002	ARC	359	6	0	100	0	0	0
Banana	*Musa*	BRA004	CNPMF	335	5	65	0	5	1	30
Banana	*Musa*	PNG004	SRC Laloki	255	4	1	99	0	0	0
Banana	*Musa*	FJI049	CePaCT	229	4	0	100	0	0	0
Banana	*Musa*	COL004	AGROSAVIA	193	3	0	47	0	52	1
Banana	*Musa*	USA108	MAY	176	3	0	0	88	7	5
Banana	*Musa*	CRI011	CORBANA	174	3	9	64	0	0	27
Banana	*Musa*	MYS142	HRC, MARDI	170	3	6	84	0	10	0
Banana	*Musa*	PHL152	NARC-LSU	149	2	5	87	7	0	0
Banana	*Musa*	GBR004	RBG	131	2	100	0	0	0	0
Banana	*Musa*	PHL129	IPB-NPGRL	98	2	0	0	0	0	100
Banana	*Musa*	ECU308	EECA	91	1	0	0	0	0	100
Banana	*Musa*	Others (34)		730	11	12	40	9	15	23
Banana	***Musa***	**Total**		**6 377**	**100**	**11**	**48**	**17**	**7**	**18**
Ribes	*Ribes*	RUS001	VIR	1 066	19	11	0	11	62	15
Ribes	*Ribes*	USA026	COR	1 062	18	51	6	6	33	5
Ribes	*Ribes*	CHE063	PSR	720	13	0	0	0	0	100
Ribes	*Ribes*	BLR017	IFG	614	11	0	0	43	57	0
Ribes	*Ribes*	UKR029	LFS	396	7	0	4	0	34	62

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Ribes	*Ribes*	GBR030	NFC	368	6	0	0	0	0	100
Ribes	*Ribes*	UKR034	MIS	229	4	0	3	19	74	4
Ribes	*Ribes*	CZE031	HOLOVOU	200	3	0	12	0	44	45
Ribes	*Ribes*	Others (51)		1 102	19	14	12	3	40	31
Ribes	***Ribes***	**Total**		**5 757**	**100**	**14**	**4**	**9**	**38**	**34**
Mango	*Mangifera*	USA047	MIA	297	16	0	0	1	62	37
Mango	*Mangifera*	BRA017	CPATSA	171	9	0	0	0	1	99
Mango	*Mangifera*	PRT102	ISOPlexis	135	7	0	100	0	0	0
Mango	*Mangifera*	BRA142	CPAMN	135	7	0	0	0	100	0
Mango	*Mangifera*	ESP048	ICIA	92	5	0	0	0	96	4
Mango	*Mangifera*	COL017	AGROSAVIA	91	5	0	0	0	70	30
Mango	*Mangifera*	Others (40)		941	51	0	30	22	19	30
Mango	***Mangifera***	**Total**		**1 862**	**100**	**0**	**22**	**11**	**35**	**32**
Peach palm	*Bactris*	CRI134	CATIE	614	44	0	100	0	0	0
Peach palm	*Bactris*	COL096	AGROSAVIA	187	13	0	69	19	11	1
Peach palm	*Bactris*	KEN023	ICRAF	157	11	0	100	0	0	0
Peach palm	*Bactris*	PER016	INIA-EEA.SR.	113	8	100	0	0	0	0
Peach palm	*Bactris*	BRA014	CNPSO	103	7	0	73	0	0	27
Peach palm	*Bactris*	BRA018	CPATU	73	5	0	0	0	0	100
Peach palm	*Bactris*	Others (12)		156	11	1	11	1	14	72
Peach palm	***Bactris***	**Total**		**1 403**	**100**	**8**	**71**	**3**	**3**	**15**
NUTS										
Hazelnut	*Corylus*	USA026	COR	743	32	17	1	31	51	0
Hazelnut	*Corylus*	ESP014	IRTAMB	268	11	0	37	22	1	40
Hazelnut	*Corylus*	BLR017	IFG	198	8	0	3	94	4	0
Hazelnut	*Corylus*	UKR046	KPS	188	8	0	0	0	2	98
Hazelnut	*Corylus*	AZE009	FTGRÍ	160	7	0	21	50	29	0
Hazelnut	*Corylus*	RUS001	VIR	106	5	5	25	5	66	0
Hazelnut	*Corylus*	Others (30)		548	23	13	15	6	39	27
Hazelnut	***Corylus***	**Total**		**2 211**	**95**	**9**	**11**	**27**	**33**	**20**
Cashew	*Anacardium*	BRA146	CNPAT	605	64	0	0	0	0	100
Cashew	*Anacardium*	PAN076	FE RIO HATO SUR - CIARG	100	11	100	0	0	0	0
Cashew	*Anacardium*	VNM085	WASI	49	5	0	0	0	100	0
Cashew	*Anacardium*	CUB003	IIFT	47	5	0	100	0	0	0
Cashew	*Anacardium*	BRA142	CPAMN	37	4	100	0	0	0	0
Cashew	*Anacardium*	MDG018	FOFIFA-Mahajanga	23	2	0	0	0	100	0
Cashew	*Anacardium*	Others (23)		88	9	5	48	14	0	34

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cashew	***Anacardium***	**Total**		**949**	**100**	**15**	**9**	**1**	**8**	**67**
Pistachio	*Pistacia*	USA028	DAV	219	29	75	1	5	1	18
Pistachio	*Pistacia*	TUN029	BNG	184	25	13	87	0	0	0
Pistachio	*Pistacia*	GBR004	RBG	55	7	100	0	0	0	0
Pistachio	*Pistacia*	ISR002	IGB	48	6	100	0	0	0	0
Pistachio	*Pistacia*	ITA378	CREA-OFA-RM	48	6	0	0	0	0	100
Pistachio	*Pistacia*	ESP133	IMIDA-FRU	41	5	0	0	0	0	100
Pistachio	*Pistacia*	ESP222	CAC	37	5	0	0	0	0	100
Pistachio	*Pistacia*	Others (21)		116	16	49	27	2	7	16
Pistachio	***Pistacia***	**Total**		**748**	**100**	**47**	**26**	**2**	**1**	**24**
OIL PLANTS										
Soybean	*Glycine*	USA033	SOY	22 490	19	10	74	5	7	3
Soybean	*Glycine*	JPN183	NARO	14 276	12	23	43	34	0	0
Soybean	*Glycine*	BRA014	CNPSO	14 201	12	0	0	0	0	100
Soybean	*Glycine*	TWN001	AVRDC	13 794	12	9	91	0	0	1
Soybean	*Glycine*	BRA003	CENARGEN	9 879	8	0	0	0	32	68
Soybean	*Glycine*	RUS001	VIR	7 109	6	5	8	41	45	0
Soybean	*Glycine*	IND001	NBPGR	5 394	5	0	2	9	1	88
Soybean	*Glycine*	NGA039	IITA	4 575	4	0	62	0	0	38
Soybean	*Glycine*	AUS165	AGG	2 430	2	4	0	37	53	6
Soybean	*Glycine*	UKR001	IR	2 338	2	5	5	31	58	1
Soybean	*Glycine*	THA300	GB-DOA	2 153	2	0	0	100	0	0
Soybean	*Glycine*	DEU146	IPK	2 020	2	1	30	39	30	0
Soybean	*Glycine*	PAK001	PGRP	1 294	1	0	2	7	13	77
Soybean	*Glycine*	COL017	AGROSAVIA	1 235	1	0	0	0	0	100
Soybean	*Glycine*	POL003	IHAR	1 204	1	0	3	0	1	96
Soybean	*Glycine*	CAN004	PGRC	1 125	1	2	0	23	62	13
Soybean	*Glycine*	ROM002	INCDA Fundulea	1 024	1	0	0	62	38	0
Soybean	*Glycine*	Others (88)		11 294	10	5	10	35	21	29
Soybean	**Glycine**	***Total***		**117 835**	**100**	**7**	**35**	**16**	**13**	**30**
Sesame	*Sesamum*	IND001	NBPGR	10 288	35	1	1	1	0	97
Sesame	*Sesamum*	KEN212	GeRRI	2 491	9	2	3	0	0	96
Sesame	*Sesamum*	JPN183	NARO	1 788	6	1	40	60	0	0
Sesame	*Sesamum*	BRA003	CENARGEN	1 528	5	0	0	0	79	21
Sesame	*Sesamum*	RUS001	VIR	1 512	5	0	0	0	0	100
Sesame	*Sesamum*	UZB006	UzRIPI	1 500	5	0	0	2	45	52
Sesame	*Sesamum*	USA016	S9	1 215	4	0	14	1	13	72
Sesame	*Sesamum*	BRA007	CNPA	852	3	0	0	0	0	100

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Sesame	*Sesamum*	PAK001	PGRP	839	3	0	26	22	2	49
Sesame	*Sesamum*	MEX006	BANGEV	785	3	0	100	0	0	0
Sesame	*Sesamum*	ETH085	EBI	711	2	0	99	0	0	1
Sesame	*Sesamum*	Others (56)		5 780	20	2	49	36	2	11
Sesame	***Sesamum***	**Total**		**29 289**	**100**	**1**	**19**	**12**	**7**	**61**
Sunflower	*Helianthus*	USA020	NC7	5 249	20	49	2	21	9	19
Sunflower	*Helianthus*	FRA015	INRAe	2 170	8	0	4	96	0	0
Sunflower	*Helianthus*	RUS001	VIR	2 129	8	2	38	58	2	0
Sunflower	*Helianthus*	BRA003	CENARGEN	1 890	7	0	0	0	26	74
Sunflower	*Helianthus*	IND001	NBPGR	1 733	6	0	7	4	4	85
Sunflower	*Helianthus*	AUS165	AGG	1 528	6	17	1	46	17	18
Sunflower	*Helianthus*	BRA014	CNPSO	1 295	5	0	0	0	0	100
Sunflower	*Helianthus*	POL003	IHAR	1 142	4	0	3	0	1	96
Sunflower	*Helianthus*	HUN003	NODiK	1 064	4	0	31	0	60	9
Sunflower	*Helianthus*	MAR088	INRA CRRAS	1 014	4	0	0	0	0	100
Sunflower	*Helianthus*	CAN004	PGRC	811	3	4	0	16	53	26
Sunflower	*Helianthus*	Others (100)		6 855	26	10	27	27	10	25
Sunflower	***Helianthus***	**Total**		**26 880**	**100**	**14**	**12**	**27**	**12**	**36**
Safflower	*Carthamus*	IND001	NBPGR	7 227	44	0	1	0	0	99
Safflower	*Carthamus*	USA022	W6	2 454	15	17	51	8	10	13
Safflower	*Carthamus*	BRA003	CENARGEN	1 851	11	0	0	0	0	100
Safflower	*Carthamus*	PAK001	PGRP	829	5	0	1	77	0	21
Safflower	*Carthamus*	ARE003	ICBA	642	4	0	100	0	0	0
Safflower	*Carthamus*	AUS165	AGG	595	4	1	0	17	16	66
Safflower	*Carthamus*	Others (61)		2 782	17	5	21	10	13	51
Safflower	***Carthamus***	**Total**		**16 380**	**100**	**4**	**16**	**7**	**4**	**69**
Rapeseed	*Brassica*	AUS165	AGG	1 507	12	1	4	20	59	16
Rapeseed	*Brassica*	DEU271	IPK	1 199	9	2	3	30	63	2
Rapeseed	*Brassica*	JPN183	NARO	968	8	0	5	95	0	0
Rapeseed	*Brassica*	CZE122	CRI	843	7	0	0	18	81	0
Rapeseed	*Brassica*	BLR011	RPC-AF	820	6	0	0	58	42	0
Rapeseed	*Brassica*	UKR013	IHK	789	6	0	1	11	82	6
Rapeseed	*Brassica*	PAK001	PGRP	733	6	0	8	57	13	22
Rapeseed	*Brassica*	USA020	NC7	660	5	2	1	1	19	77
Rapeseed	*Brassica*	BRA003	CENARGEN	551	4	0	0	0	2	98
Rapeseed	*Brassica*	CAN004	PGRC	538	4	0	3	3	77	16
Rapeseed	*Brassica*	POL003	IHAR	475	4	0	6	0	32	63
Rapeseed	*Brassica*	Others (73)		3 552	28	3	21	14	44	17

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Rapeseed	***Brassica***	**Total**		**12 635**	**100**	**1**	**8**	**26**	**45**	**20**
Olive	*Olea*	ITA401	CREA-OFA-REN	993	34	0	76	22	1	2
Olive	*Olea*	ESP046	IFAPACOR	425	15	0	100	0	0	0
Olive	*Olea*	PRT196	INIAV-Elvas	273	9	0	12	0	0	88
Olive	*Olea*	ITA443	CRFSA	192	7	0	100	0	0	0
Olive	*Olea*	TUN029	BNG	186	6	2	98	0	0	0
Olive	*Olea*	USA028	DAV	159	5	3	0	1	7	89
Olive	*Olea*	UKR036	NBS	157	5	0	4	0	17	80
Olive	*Olea*	Others (38)		519	18	8	72	9	7	4
Olive	***Olea***	**Total**		**2 904**	**100**	**2**	**68**	**9**	**3**	**19**
Oil palm	*Elaeis*	BRA027	CPAA	575	70	0	0	0	0	100
Oil palm	*Elaeis*	BRA018	CPATU	171	21	0	0	0	0	100
Oil palm	*Elaeis*	CRI134	CATIE	35	4	0	91	9	0	0
Oil palm	*Elaeis*	Others (9)		46	6	2	24	26	2	46
Oil palm	***Elaeis***	**Total**		**827**	**100**	**0**	**5**	**2**	**0**	**93**
FORAGES										
Clover	*Trifolium*	AUS167	APG	20 442	25	95	0	1	2	1
Clover	*Trifolium*	NZL001	AGRESEARCH	10 909	13	0	0	0	0	100
Clover	*Trifolium*	GBR016	IBERS-GRU	6 400	8	25	2	31	11	32
Clover	*Trifolium*	LBN002	ICARDA	5 519	7	83	3	0	0	13
Clover	*Trifolium*	RUS001	VIR	4 598	6	38	31	5	20	5
Clover	*Trifolium*	ESP010	SIAEX	4 418	5	96	0	1	1	2
Clover	*Trifolium*	USA022	W6	3 729	5	47	3	4	22	24
Clover	*Trifolium*	USA016	S9	2 599	3	47	5	1	10	37
Clover	*Trifolium*	ITA394	CREA-ZA-LO	2 214	3	94	1	1	4	0
Clover	*Trifolium*	ETH013	ILRI-Ethiopia	1 511	2	95	0	0	5	0
Clover	*Trifolium*	JPN183	NARO	1 405	2	50	9	41	0	0
Clover	*Trifolium*	DEU146	IPK	1 093	1	61	0	1	19	19
Clover	*Trifolium*	Others (96)		17 196	21	42	7	9	13	29
Clover	***Trifolium***	**Total**		**82 033**	**100**	**57**	**4**	**6**	**7**	**26**
Medicago	*Medicago*	AUS167	APG	27 662	34	93	1	2	3	2
Medicago	*Medicago*	LBN002	ICARDA	9 779	12	92	4	0	0	4
Medicago	*Medicago*	USA022	W6	8 627	11	55	8	4	20	13
Medicago	*Medicago*	RUS001	VIR	4 253	5	35	40	5	21	0
Medicago	*Medicago*	MAR088	INRA CRRAS	3 401	4	95	0	0	5	0
Medicago	*Medicago*	TUN029	BNG	3 371	4	0	0	0	0	100
Medicago	*Medicago*	FRA041	INRAe-MONTPEL	2 457	3	32	2	0	0	66
Medicago	*Medicago*	JPN183	NARO	1 466	2	16	4	80	0	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Medicago	*Medicago*	CAN004	PGRC	1 379	2	22	14	3	28	34
Medicago	*Medicago*	GBR016	IBERS-GRU	1 317	2	15	1	3	21	60
Medicago	*Medicago*	ITA363	PERUG	1 302	2	12	9	51	5	23
Medicago	*Medicago*	NZL001	AGRESEARCH	1 286	2	0	0	0	0	100
Medicago	*Medicago*	Others (98)		14 069	18	35	12	10	22	21
Medicago	***Medicago***	**Total**		**80 369**	**100**	**63**	**6**	**6**	**9**	**16**
Vicia	*Vicia*	LBN002	ICARDA	6 419	20	50	10	1	0	39
Vicia	*Vicia*	RUS001	VIR	4 107	13	12	12	7	5	64
Vicia	*Vicia*	AUS165	AGG	2 914	9	10	0	0	0	89
Vicia	*Vicia*	GBR004	RBG	2 032	6	98	0	0	0	2
Vicia	*Vicia*	DEU146	IPK	1 808	6	6	46	3	12	34
Vicia	*Vicia*	USA022	W6	1 807	6	45	14	0	6	35
Vicia	*Vicia*	ESP004	INIA-CRF	1 693	5	18	77	2	2	1
Vicia	*Vicia*	BGR001	IPGR	1 404	4	17	0	0	0	82
Vicia	*Vicia*	Others (96)		9 245	29	30	27	5	8	30
Vicia	***Vicia***	**Total**		**31 429**	**100**	**32**	**19**	**3**	**4**	**41**
Grasses	*Lolium*	GBR016	IBERS-GRU	4 744	17	41	1	30	21	7
Grasses	*Lolium*	NZL001	AGRESEARCH	4 425	16	0	0	0	0	100
Grasses	*Lolium*	DEU271	IPK	3 831	14	63	0	4	31	2
Grasses	*Lolium*	POL003	IHAR	2 902	10	4	0	0	4	92
Grasses	*Lolium*	JPN183	NARO	1 704	6	19	1	80	0	0
Grasses	*Lolium*	USA022	W6	1 388	5	43	6	0	28	23
Grasses	*Lolium*	AUS167	APG	983	4	39	1	1	47	12
Grasses	*Lolium*	Others (74)		7 703	28	31	7	10	33	19
Grasses	***Lolium***	**Total**		**27 680**	**100**	**30**	**3**	**13**	**21**	**34**
Fescue	*Festuca*	POL003	IHAR	4 001	15	9	0	0	2	89
Fescue	*Festuca*	JPN183	NARO	2 764	11	23	7	71	0	0
Fescue	*Festuca*	USA022	W6	2 654	10	65	6	1	15	14
Fescue	*Festuca*	DEU271	IPK	2 312	9	60	0	4	28	8
Fescue	*Festuca*	RUS001	VIR	2 041	8	62	5	9	25	0
Fescue	*Festuca*	Others (73)		12 081	47	49	2	4	14	31
Fescue	***Festuca***	**Total**		**25 853**	**100**	**43**	**3**	**10**	**13**	**31**
Grasses	*Dactylis*	POL003	IHAR	6 236	29	92	0	0	3	5
Grasses	*Dactylis*	JPN183	NARO	2 343	11	40	8	52	0	0
Grasses	*Dactylis*	DEU271	IPK	1 920	9	80	0	4	13	2
Grasses	*Dactylis*	USA022	W6	1 622	8	58	8	4	8	21
Grasses	*Dactylis*	NZL001	AGRESEARCH	1 340	6	0	0	0	0	100
Grasses	*Dactylis*	RUS001	VIR	1 167	5	74	6	4	16	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Grasses	*Dactylis*	GBR016	IBERS-GRU	1 049	5	71	2	10	10	7
Grasses	*Dactylis*	Others (73)		5 567	26	60	4	6	12	17
Grasses	***Dactylis***	**Total**		**21 244**	**100**	**66**	**3**	**9**	**7**	**15**
Grasses	*Poa*	POL003	IHAR	2 832	25	18	0	0	2	80
Grasses	*Poa*	USA022	W6	2 288	20	85	1	1	9	4
Grasses	*Poa*	RUS001	VIR	1 530	13	74	15	6	5	0
Grasses	*Poa*	DEU271	IPK	1 223	11	60	0	3	30	7
Grasses	*Poa*	SWE054	NORDGEN	569	5	83	4	2	11	0
Grasses	*Poa*	NZL001	AGRESEARCH	451	4	0	0	0	0	100
Grasses	*Poa*	Others (57)		2 468	22	58	3	12	18	8
Grasses	***Poa***	**Total**		**11 361**	**100**	**55**	**3**	**4**	**11**	**27**
Pencilflower	*Stylosanthes*	COL003	CIAT	4 194	39	99	0	0	0	0
Pencilflower	*Stylosanthes*	AUS167	APG	2 050	19	98	0	1	2	0
Pencilflower	*Stylosanthes*	ETH013	ILRI-Ethiopia	1 126	10	98	0	0	2	0
Pencilflower	*Stylosanthes*	KEN212	GeRRI	1 059	10	3	90	0	0	8
Pencilflower	*Stylosanthes*	BRA034	CPAC	946	9	0	0	0	0	100
Pencilflower	*Stylosanthes*	BRA003	CENARGEN	879	8	1	0	0	5	94
Pencilflower	*Stylosanthes*	Others (24)		634	6	16	9	17	4	54
Pencilflower	***Stylosanthes***	**Total**		**10 888**	**100**	**68**	**9**	**1**	**1**	**20**
Trefoil	*Lotus*	AUS167	APG	2 740	27	79	1	15	4	1
Trefoil	*Lotus*	NZL001	AGRESEARCH	1 526	15	0	0	0	0	100
Trefoil	*Lotus*	USA022	W6	922	9	57	1	4	15	23
Trefoil	*Lotus*	GBR016	IBERS-GRU	537	5	22	1	29	12	36
Trefoil	*Lotus*	TUN029	BNG	491	5	1	0	0	0	99
Trefoil	*Lotus*	RUS001	VIR	440	4	61	5	0	22	12
Trefoil	*Lotus*	ARE003	ICBA	414	4	100	0	0	0	0
Trefoil	*Lotus*	Others (78)		3 017	30	49	8	8	9	26
Trefoil	***Lotus***	**Total**		**10 087**	**100**	**49**	**3**	**9**	**7**	**33**
Grasses	*Cenchrus*	IND001	NBPGR	1 816	19	2	0	0	0	98
Grasses	*Cenchrus*	USA016	S9	1 409	15	28	0	0	0	71
Grasses	*Cenchrus*	KEN212	GeRRI	1 403	15	6	2	0	0	92
Grasses	*Cenchrus*	ARE003	ICBA	770	8	100	0	0	0	0
Grasses	*Cenchrus*	IND002	ICRISAT	714	8	98	0	2	0	0
Grasses	*Cenchrus*	GBR016	IBERS-GRU	469	5	75	0	1	3	21
Grasses	*Cenchrus*	Others (49)		2 836	30	57	1	15	13	15
Grasses	***Cenchrus***	**Total**		**9 417**	**100**	**42**	**1**	**5**	**4**	**49**
Grasses	*Phleum*	POL003	IHAR	2 873	31	7	0	0	1	91
Grasses	*Phleum*	RUS001	VIR	1 478	16	61	22	6	11	0

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Grasses	*Phleum*	DEU271	IPK	1 104	12	73	2	2	18	5
Grasses	*Phleum*	SWE054	NORDGEN	837	9	66	20	5	9	0
Grasses	*Phleum*	USA022	W6	705	8	40	10	0	16	35
Grasses	*Phleum*	NZL001	AGRESEARCH	508	5	0	0	0	0	100
Grasses	*Phleum*	Others (55)		1 826	20	39	6	12	28	14
Grasses	***Phleum***	**Total**		**9 331**	**100**	**37**	**7**	**4**	**12**	**40**
Grasses	*Bromus*	USA022	W6	1 258	15	69	5	1	9	17
Grasses	*Bromus*	NZL001	AGRESEARCH	1 254	15	0	0	0	0	100
Grasses	*Bromus*	RUS001	VIR	958	12	73	11	5	11	0
Grasses	*Bromus*	CHL150	INIA Carillanca	662	8	0	0	100	0	0
Grasses	*Bromus*	ROM080	SCDP Vaslui	371	5	0	0	94	6	0
Grasses	*Bromus*	CAN004	PGRC	320	4	70	0	2	20	7
Grasses	*Bromus*	DEU146	IPK	307	4	31	0	0	2	66
Grasses	*Bromus*	ARG1351	BGANGUIL	295	4	6	0	93	1	0
Grasses	*Bromus*	CHL171	SAG	278	3	100	0	0	0	0
Grasses	*Bromus*	Others (63)		2 535	31	51	1	12	9	27
Grasses	***Bromus***	**Total**		**8 238**	**100**	**42**	**2**	**20**	**7**	**29**
Rye	*Elymus*	USA022	W6	2 511	43	92	3	0	1	3
Rye	*Elymus*	RUS001	VIR	645	11	84	3	7	6	0
Rye	*Elymus*	NZL001	AGRESEARCH	520	9	0	0	0	0	100
Rye	*Elymus*	AUS165	AGG	259	4	100	0	0	0	0
Rye	*Elymus*	IND001	NBPGR	255	4	100	0	0	0	0
Rye	*Elymus*	Others (54)		1 600	28	65	1	13	4	18
Rye	***Elymus***	**Total**		**5 790**	**100**	**76**	**2**	**5**	**2**	**15**
Grasses	*Andropogon*	USA995	NCGRP	966	55	0	0	0	0	100
Grasses	*Andropogon*	USA016	S9	313	18	52	0	0	4	44
Grasses	*Andropogon*	KEN212	GeRRI	116	7	1	0	0	0	99
Grasses	*Andropogon*	ETH013	ILRI-Ethiopia	103	6	98	0	0	2	0
Grasses	*Andropogon*	COL003	CIAT	89	5	99	0	0	1	0
Grasses	*Andropogon*	AUS167	APG	56	3	95	0	0	5	0
Grasses	*Andropogon*	Others (22)		115	7	65	3	7	6	19
Grasses	***Andropogon***	**Total**		**1 758**	**100**	**27**	**0**	**1**	**2**	**70**
SUGAR CROPS										
Beet	*Beta*	USA022	W6	2 688	22	28	31	22	15	4
Beet	*Beta*	DEU146	IPK	2 350	19	47	22	5	24	3
Beet	*Beta*	JPN183	NARO	900	7	3	0	97	0	0
Beet	*Beta*	POL003	IHAR	774	6	3	33	31	22	10
Beet	*Beta*	HUN003	NODiK	449	4	0	28	0	40	32

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Beet	*Beta*	BLR011	RPC-AF	371	3	0	0	58	42	0
Beet	*Beta*	UKR014	ICB	352	3	12	1	42	4	41
Beet	*Beta*	Others (92)		4 435	36	15	20	11	23	31
Beet	***Beta***	**Total**		**12 319**	**100**	**21**	**21**	**22**	**20**	**16**
Sugar cane	*Saccharum*	CUB041	INICA	3 175	28	3	5	62	31	0
Sugar cane	*Saccharum*	JPN183	NARO	1 656	15	37	3	60	0	0
Sugar cane	*Saccharum*	COL115	CENICAÑA	1 519	14	0	0	4	96	0
Sugar cane	*Saccharum*	BGD015	BSRI	1 174	10	4	96	0	0	0
Sugar cane	*Saccharum*	USA047	MIA	969	9	7	2	5	32	54
Sugar cane	*Saccharum*	VNM120	SCRDC	530	5	0	2	0	98	0
Sugar cane	*Saccharum*	ARG1217	EEA INTA Famaillá	428	4	0	0	100	0	0
Sugar cane	*Saccharum*	FRA201	CIRAD-FLHOR	423	4	0	0	1	1	97
Sugar cane	*Saccharum*	IND001	NBPGR	316	3	4	0	0	0	96
Sugar cane	*Saccharum*	KEN212	GeRRI	304	3	0	0	0	99	0
Sugar cane	*Saccharum*	Others (22)		693	6	10	8	39	7	35
Sugar cane	***Saccharum***	**Total**		**11 187**	**100**	**8**	**13**	**34**	**32**	**13**
FIBRE PLANTS										
Cotton	*Gossypium*	UZB036	UzRICBSP	12 288	17	0	0	0	0	100
Cotton	*Gossypium*	USA049	COT	10 310	14	19	2	11	6	63
Cotton	*Gossypium*	UZB001	IGPEB	9 953	14	0	33	37	30	0
Cotton	*Gossypium*	IND001	NBPGR	9 768	14	6	0	5	2	87
Cotton	*Gossypium*	UZB006	UzRIPI	6 404	9	2	15	10	35	38
Cotton	*Gossypium*	RUS001	VIR	6 334	9	2	24	20	55	0
Cotton	*Gossypium*	BRA003	CENARGEN	3 245	5	0	0	0	2	98
Cotton	*Gossypium*	PAK001	PGRP	2 056	3	0	0	98	2	0
Cotton	*Gossypium*	BRA007	CNPA	1 841	3	0	0	0	0	100
Cotton	*Gossypium*	AZE015	GRI	1 504	2	0	3	50	47	0
Cotton	*Gossypium*	Others (62)		8 064	11	7	15	24	19	35
Cotton	***Gossypium***	**Total**		**71 767**	**100**	**5**	**10**	**16**	**16**	**52**
Flax	*Linum*	RUS001	VIR	5 849	15	1	53	26	20	0
Flax	*Linum*	CAN004	PGRC	3 708	10	3	1	11	15	70
Flax	*Linum*	ETH085	EBI	3 661	10	0	99	0	0	1
Flax	*Linum*	USA020	NC7	3 001	8	4	1	0	5	89
Flax	*Linum*	IND001	NBPGR	2 947	8	0	2	0	2	96
Flax	*Linum*	ROM002	INCDA Fundulea	2 880	8	3	2	44	51	0
Flax	*Linum*	DEU146	IPK	2 323	6	2	39	15	40	3
Flax	*Linum*	CZE122	CRI	2 207	6	0	23	27	48	1
Flax	*Linum*	BGR001	IPGR	1 482	4	0	3	0	2	95

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Flax	*Linum*	UKR015	ILK	1 333	3	1	12	10	71	5
Flax	*Linum*	Others (86)		8 873	23	3	12	35	23	27
Flax	***Linum***	**Total**		**38 264**	**100**	**2**	**25**	**19**	**22**	**32**
Jute	*Corchorus*	BGD001	BJRI	4 229	43	7	8	4	0	81
Jute	*Corchorus*	IND001	NBPGR	3 468	35	12	1	0	0	86
Jute	*Corchorus*	TWN001	AVRDC	330	3	0	79	0	0	21
Jute	*Corchorus*	KEN212	GeRRI	224	2	21	68	0	0	11
Jute	*Corchorus*	UZB006	UzRIPI	168	2	0	0	2	6	92
Jute	*Corchorus*	RUS001	VIR	162	2	0	0	0	0	100
Jute	*Corchorus*	Others (42)		1 242	13	16	60	14	2	9
Jute	***Corchorus***	**Total**		**9 823**	**100**	**10**	**15**	**4**	**1**	**71**
SPICES, STIMULANT CROPS AND MEDICINAL PLANTS										
Mustard	*Brassica*	IND001	NBPGR	8 150	44	0	2	1	1	96
Mustard	*Brassica*	AUS165	AGG	1 805	10	5	9	16	15	55
Mustard	*Brassica*	RUS001	VIR	1 298	7	0	2	1	0	96
Mustard	*Brassica*	PAK001	PGRP	1 197	6	0	16	76	3	5
Mustard	*Brassica*	CAN004	PGRC	758	4	17	32	8	24	20
Mustard	*Brassica*	ETH085	EBI	691	4	0	85	0	0	15
Mustard	*Brassica*	Others (74)		4 548	25	7	35	6	9	43
Mustard	***Brassica***	**Total**		**18 447**	**100**	**3**	**16**	**9**	**5**	**67**
Tobacco	*Nicotiana*	IND001	NBPGR	2 269	15	0	0	0	0	99
Tobacco	*Nicotiana*	USA074	TOB	2 227	15	7	5	13	28	47
Tobacco	*Nicotiana*	ITA403	CREA-CI-LAB-CE	1 557	10	84	0	0	16	0
Tobacco	*Nicotiana*	AUS165	AGG	1 093	7	39	3	46	11	2
Tobacco	*Nicotiana*	UKR079	KST	1 081	7	0	7	13	19	62
Tobacco	*Nicotiana*	POL003	IHAR	1 041	7	8	9	5	70	9
Tobacco	*Nicotiana*	CUB323	EET-SJM	882	6	7	8	70	16	0
Tobacco	*Nicotiana*	DEU594	LTZ	786	5	0	0	0	0	100
Tobacco	*Nicotiana*	DEU146	IPK	590	4	16	26	9	37	13
Tobacco	*Nicotiana*	Others (65)		3 567	24	5	21	14	23	37
Tobacco	***Nicotiana***	**Total**		**15 093**	**100**	**15**	**9**	**14**	**21**	**41**
Coffee	*Coffea*	ETH085	EBI	4 520	43	0	100	0	0	0
Coffee	*Coffea*	CRI134	CATIE	1 990	19	0	51	49	0	0
Coffee	*Coffea*	FRA254	IRD	807	8	83	8	1	0	9
Coffee	*Coffea*	ECU330	EETP	557	5	0	0	0	0	100
Coffee	*Coffea*	PRT018	ISA	503	5	0	0	94	5	0
Coffee	*Coffea*	GUF001	CIRAD	477	5	2	6	34	4	54
Coffee	*Coffea*	VNM085	WASI	233	2	0	0	0	100	0

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Coffee	*Coffea*	ECU023	DENAREF	230	2	0	0	0	0	100
Coffee	*Coffea*	Others (30)		1 148	11	15	4	17	43	20
Coffee	***Coffea***	**Total**		**10 465**	**100**	**8**	**54**	**17**	**7**	**13**
Opium	*Papaver*	TUR001	AARI	2 387	28	0	100	0	0	0
Opium	*Papaver*	DEU146	IPK	1 137	13	4	59	3	20	14
Opium	*Papaver*	UKR008	UDS	1 090	13	0	3	28	1	68
Opium	*Papaver*	HUN003	NODiK	1 026	12	0	67	0	13	20
Opium	*Papaver*	IND001	NBPGR	536	6	0	19	0	9	72
Opium	*Papaver*	USA022	W6	343	4	81	2	0	1	16
Opium	*Papaver*	POL003	IHAR	338	4	3	14	0	6	77
Opium	*Papaver*	SVK002	SVKMSARIS	265	3	0	48	28	23	1
Opium	*Papaver*	BGR001	IPGR	247	3	0	3	0	0	96
Opium	*Papaver*	Others (54)		1 234	14	24	27	3	15	29
Opium	***Papaver***	**Total**		**8 603**	**100**	**7**	**51**	**5**	**8**	**28**
Cocoa	*Theobroma*	ECU330	EETP	2 226	27	0	0	0	0	100
Cocoa	*Theobroma*	CRI142	CATIE	1 242	15	1	87	13	0	0
Cocoa	*Theobroma*	ECU023	DENAREF	553	7	0	0	0	0	100
Cocoa	*Theobroma*	FRA014	CIRAD	519	6	61	6	21	1	10
Cocoa	*Theobroma*	COL032	AGROSAVIA	464	6	0	0	0	100	0
Cocoa	*Theobroma*	SLV050	CENTA	355	4	0	11	0	89	0
Cocoa	*Theobroma*	BRA018	CPATU	327	4	0	0	53	0	47
Cocoa	*Theobroma*	USA108	MAY	293	4	0	0	86	4	10
Cocoa	*Theobroma*	CUB299	EICB	290	4	0	6	94	0	0
Cocoa	*Theobroma*	ECU308	EECA	275	3	0	0	0	0	100
Cocoa	*Theobroma*	Others (24)		1 619	20	10	25	30	23	13
Cocoa	***Theobroma***	**Total**		**8 163**	**100**	**6**	**19**	**18**	**14**	**43**
Tea	*Camellia*	JPN183	NARO	6 435	93	2	63	34	0	0
Tea	*Camellia*	BGD012	BTRI	267	4	2	53	30	14	0
Tea	*Camellia*	VNM025	VINATRI	193	3	0	20	0	80	0
Tea	*Camellia*	USA151	NAGU	36	1	14	6	0	0	81
Tea	*Camellia*	AZE009	FTGRÍ	11	0	0	0	0	100	0
Tea	*Camellia*	Others (9)		11	0	36	45	9	0	9
Tea	***Camellia***	**Total**		**6 953**	**100**	**2**	**61**	**33**	**3**	**0**
MATERIAL										
Castor seed	*Ricinus*	IND001	NBPGR	2 690	34	0	1	1	1	98
Castor seed	*Ricinus*	RUS001	VIR	1 208	15	0	0	100	0	0
Castor seed	*Ricinus*	USA995	NCGRP	665	9	0	0	0	0	100
Castor seed	*Ricinus*	BRA003	CENARGEN	639	8	0	0	0	39	61

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Castor seed	*Ricinus*	ETH085	EBI	449	6	100	0	0	0	0
Castor seed	*Ricinus*	USA016	S9	378	5	0	1	1	2	96
Castor seed	*Ricinus*	UKR012	IOK	297	4	0	0	16	4	79
Castor seed	*Ricinus*	Others (53)		1 476	19	22	31	10	1	35
Castor seed	***Ricinus***	**Total**		**7 802**	**100**	**10**	**6**	**18**	**4**	**62**
Guar	*Cyamopsis*	IND001	NBPGR	4 064	57	0	0	0	0	100
Guar	*Cyamopsis*	PAK001	PGRP	1 055	15	0	23	40	1	36
Guar	*Cyamopsis*	USA995	NCGRP	887	12	0	0	1	0	99
Guar	*Cyamopsis*	AUS165	AGG	467	7	0	27	59	3	11
Guar	*Cyamopsis*	USA016	S9	413	6	0	1	2	0	97
Guar	*Cyamopsis*	ARE003	ICBA	99	1	0	100	0	0	0
Guar	*Cyamopsis*	BRA003	CENARGEN	86	1	0	0	0	0	100
Guar	*Cyamopsis*	Others (14)		59	1	25	19	12	3	41
Guar	***Cyamopsis***	**Total**		**7 130**	**100**	**0**	**7**	**10**	**1**	**82**
Physic nut	*Jatropha*	IND001	NBPGR	2 190	52	0	3	0	0	97
Physic nut	*Jatropha*	KEN023	ICRAF	460	11	100	0	0	0	0
Physic nut	*Jatropha*	MEX020	CERI	394	9	0	100	0	0	0
Physic nut	*Jatropha*	MEX006	BANGEV	165	4	0	100	0	0	0
Physic nut	*Jatropha*	ECU023	DENAREF	159	4	0	0	0	0	100
Physic nut	*Jatropha*	PER017	INIA-EEA.POV	135	3	0	100	0	0	0
Physic nut	*Jatropha*	MEX194	ICAMEX	133	3	2	98	0	0	0
Physic nut	*Jatropha*	Others (25)		544	13	33	34	1	1	32
Physic nut	***Jatropha***	**Total**		**4 180**	**100**	**15**	**26**	**0**	**0**	**59**
ORNAMENTALS										
Rhododendron	*Rhododendron*	DEU101	BSA	11 501	80	0	0	0	81	19
Rhododendron	*Rhododendron*	JPN183	NARO	1 119	8	39	3	58	0	0
Rhododendron	*Rhododendron*	BEL094	ILVO	610	4	0	0	0	0	100
Rhododendron	*Rhododendron*	CZE079	PRUHON	584	4	0	0	0	100	0
Rhododendron	*Rhododendron*	USA151	NAGU	326	2	52	3	0	0	45
Rhododendron	*Rhododendron*	Others (12)		199	1	46	1	1	0	53
Rhododendron	***Rhododendron***	**Total**		**14 339**	**100**	**5**	**0**	**5**	**69**	**22**
Rose	*Rosa*	DEU528	Europa-Rosarium	3 674	55	2	0	0	98	0
Rose	*Rosa*	UKR036	NBS	445	7	2	0	5	92	2
Rose	*Rosa*	JPN183	NARO	406	6	6	1	93	0	0
Rose	*Rosa*	DEU630	DR-GRF	358	5	0	0	0	100	0
Rose	*Rosa*	USA151	NAGU	334	5	59	2	0	0	39
Rose	*Rosa*	POL001	PAN	241	4	0	0	0	0	100
Rose	*Rosa*	GBR004	RBG	228	3	98	0	0	0	2

(Cont.)

Crop grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Rose	*Rosa*	FRA364	RL	202	3	26	74	0	0	0
Rose	*Rosa*	Others (52)		820	12	29	2	7	50	12
Rose	***Rosa***	**Total**		**6 708**	**100**	**12**	**3**	**7**	**71**	**7**
Marigold	*Tagetes*	MEX131	UDG-CUCBA	1 107	36	92	8	0	0	0
Marigold	*Tagetes*	MEX006	BANGEV	453	15	21	75	0	0	4
Marigold	*Tagetes*	IND001	NBPGR	352	11	3	0	1	2	94
Marigold	*Tagetes*	MEX201	CRUS	282	9	100	0	0	0	0
Marigold	*Tagetes*	BGR001	IPGR	223	7	0	10	0	3	87
Marigold	*Tagetes*	USA956	OPGC	153	5	16	3	0	39	41
Marigold	*Tagetes*	Others (44)		499	16	19	38	2	17	25
Marigold	***Tagetes***	**Total**		**3 069**	**100**	**50**	**21**	**0**	**5**	**24**

Appendix 3

Species conserved in only one or only a few *ex situ* collections

List of species with a collection of 20 or more accessions conserved *ex situ* with 95 percent or more of their holdings conserved in only one genebank and less than 50 percent of their accessions safety duplicated. Full names of the institutes mentioned in the following table are given in Appendix 5.

Legend

CWR: Crop wild relatives

WFP: Wild food plants

Total accessions: Total accessions conserved *ex situ*

Genebanks: Number of holding genebanks

Minimum genebank collection size (accessions): Number of accessions in the smallest genebank collection

Maximum genebank collection size (accessions): Number of accessions in the largest genebank collection

Maximum genebank collection size (%): Size of the largest genebank collection as a percentage of total genebank collections

Safety duplication % of the maximum genebank collection: Percentage of safety duplication in the largest genebank collection

Holding institute code: WIEWS code of the genebank holding the largest collection

Holding institute acronym: Acronym of the genebank holding the largest collection

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Fruit plants	*Uapaca kirkiana*		Y	Least Concern	2 927	1	2 927	2 927	100	0	KEN023	ICRAF
Fruit plants	*Euterpe oleracea*				1 831	5	1	1 823	99.6	2	BRA018	CPATU
Fruit plants	*Sclerocarya birrea*		Y		1 808	7	1	1 786	98.8	0	KEN023	ICRAF
Fruit plants	*Strychnos cocculoides*		Y	Least Concern	1 629	3	1	1 625	99.8	0	KEN023	ICRAF
Fruit plants	*Oenocarpus mapora*	Y	Y	Least Concern	467	1	467	467	100	0	BRA018	CPATU
Fruit plants	*Pachylobus edulis*		Y		302	1	302	302	100	0	KEN023	ICRAF
Fruit plants	*Malus fusca*	Y	Y	Least Concern	245	6	1	234	95.5	37	USA167	GEN
Fruit plants	*Vitellaria paradoxa*			Vulnerable	173	1	173	173	100	0	KEN023	ICRAF
Fruit plants	*Ugni molinae*		Y		123	2	1	122	99.2	0	CHL150	INIA Carillanca
Fruit plants	*Halesia Carolina*		Y	Least Concern	118	4	1	115	97.5	46	USA151	NAGU
Fruit plants	*Annona macroprophyllata*	Y		Least Concern	117	6	1	112	95.7	0	MEX178	IT-Altamirano
Fruit plants	*Vaccinium ovalifolium*	Y	Y		103	4	1	98	95.1	49	USA026	COR
Fruit plants	*Lucuma bifera*		Y	Least Concern	100	1	100	100	100	0	PER041	INIA-EEA.CAN
Fruit plants	*Oenocarpus bataua*	Y	Y		97	2	1	96	99	0	BRA018	CPATU
Fruit plants	*Prunus takesimensis*	Y	Y	Least Concern	51	1	51	51	100	0	USA151	NAGU
Fruit plants	*Curculigo latifolia*		Y		45	1	45	45	100	0	MYS125	UPM
Fruit plants	*Vaccinium darrowii*	Y	Y		45	2	2	43	95.6	12	USA026	COR
Fruit plants	*Fragaria cascadensis*	Y	Y		42	1	42	42	100	12	USA026	COR
Fruit plants	*Oenocarpus distichus*	Y	Y		42	1	42	42	100	0	BRA018	CPATU
Fruit plants	*Cereus jamacaru*		Y	Least Concern	38	1	38	38	100	0	BRA146	CNPAT
Fruit plants	*Oenocarpus bacaba*	Y	Y		38	2	1	37	97.4	0	BRA018	CPATU
Fruit plants	*Astrocaryum murumuru*	Y	Y		33	1	33	33	100	0	BRA018	CPATU
Fruit plants	*Malus zhaojiaoensis*	Y	Y		33	1	33	33	100	6	USA167	GEN
Fruit plants	*Vaccinium reticulatum*	Y	Y		31	1	31	31	100	32	USA026	COR
Fruit plants	*Harungana madagascariensis*		Y	Least Concern	30	2	1	29	96.7	0	GBR004	RBG
Fruit plants	*Salvadora oleoides*		Y	Data Deficient	30	1	30	30	100	0	IND001	NBPGR
Fruit plants	*Vaccinium smallii*	Y	Y		30	1	30	30	100	23	USA026	COR
Fruit plants	*Mauritia flexuosa*				29	1	29	29	100	0	BRA239	CPAFAP
Fruit plants	*Rubus trivialis*	Y			29	2	1	28	96.6	18	USA026	COR
Fruit plants	*Spondias bahiensis*	Y			29	1	29	29	100	0	BRA004	CNPMF

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Fruit plants	*Caryocar brasiliense*		Y	Least Concern	28	1	28	28	100	0	BRA034	CPAC
Fruit plants	*Crataegus nelsonii*		Y		26	1	26	26	100	0	MEX051	UACh
Fruit plants	*Gaylussacia brachycera*		Y		25	2	1	24	96	0	USA151	NAGU
Fruit plants	*Myrica rubra*		Y		25	2	1	24	96	0	JPN183	NARO
Fruit plants	*Butia odorata*		Y		22	1	22	22	100	0	BRA020	CPACT/Embrapa
Fruit plants	*Stenocereus queretaroensis*			Least Concern	22	2	1	21	95.5	0	MEX121	CICTAMEX
Fruit plants	*Rubus crataegifolius*	Y			20	1	20	20	100	30	USA026	COR
Nuts	*Carya illinoinensis*			Least Concern	3 733	10	1	3 615	96.8	0	USA133	BRW
Nuts	*Acrocomia aculeata*	Y	Y	Least Concern	1 526	6	1	1 488	97.5	0	BRA034	CPAC
Nuts	*Irvingia tenuinucleata*		Y		422	1	422	422	100	0	KEN023	ICRAF
Nuts	*Euryale ferox*			Least Concern	352	1	352	352	100	0	IND001	NBPGR
Nuts	*Corylus cornuta*	Y		Least Concern	64	3	1	62	96.9	2	USA026	COR
Nuts	*Carya texana*	Y	Y	Least Concern	48	2	1	47	97.9	0	USA133	BRW
Nuts	*Pinus koraiensis*	Y	Y	Least Concern	48	2	2	46	95.8	11	USA151	NAGU
Nuts	*Carya nussbaumeri*	Y			23	1	23	23	100	0	USA133	BRW
Nuts	*Juglans neotropica*	Y	Y	Endangered	23	2	1	22	95.7	0	ECU212	JBQ
Nuts	*Lecythis pisonis*		Y		23	1	23	23	100	0	BRA142	CPAMN
Nuts	*Carya lecontei*	Y			21	1	21	21	100	0	USA133	BRW
Roots & tubers	*Ensete ventricosum*	Y		Least Concern	310	6	1	303	97.7	0	ETH085	EBI
Roots & tubers	*Dioscorea burkilliana*	Y	Y	Least Concern	300	1	300	300	100	0	NGA039	IITA
Roots & tubers	*Dioscorea praehensilis*	Y		Least Concern	249	3	1	247	99.2	0	GHA091	PGRRI
Roots & tubers	*Dioscorea abyssinica*	Y	Y	Least Concern	92	1	92	92	100	0	NGA039	IITA
Roots & tubers	*Manihot peruviana*	Y			91	1	91	91	100	0	COL003	CIAT
Roots & tubers	*Coleus maculosus*				71	3	1	68	95.8	0	ETH085	EBI
Roots & tubers	*Coccinia abyssinica*				40	1	40	40	100	0	ETH085	EBI
Roots & tubers	*Dioscorea sambiranensis*	Y	Y	Near Threatened	33	1	33	33	100	0	GBR004	RBG
Roots & tubers	*Zamia integrifolia*		Y	Near Threatened	27	1	27	27	100	0	USA047	MIA
Roots & tubers	*Alocasia odora*	Y	Y	Least Concern	26	1	26	26	100	0	VNM049	PRC
Pulses	*Vigna minima*	Y	Y		558	7	1	547	98	0	JPN183	NARO

(Cont.)

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Pulses	*Vigna reflexopilosa*	Y			122	4	1	119	97.5	0	JPN183	NARO
Pulses	*Arachis prostrata*	Y			85	2	3	82	96.5	0	BRA003	CENARGEN
Pulses	*Vigna exilis*	Y		Near Threatened	42	2	1	41	97.6	0	JPN183	NARO
Pulses	*Vigna grandiflora*	Y		Near Threatened	42	2	1	41	97.6	0	JPN183	NARO
Pulses	*Amphicarpaea edgeworthii*		Y		34	1	34	34	100	0	JPN183	NARO
Cereals	*Digitaria ciliaris*	Y			469	8	1	446	95.1	0	JPN183	NARO
Cereals	*Echinochloa oryzoides*	Y			358	5	1	348	97.2	0	JPN183	NARO
Cereals	*Hordeum nutans*	Y			31	1	31	31	100	0	MNG030	IPAS
Vegetables	*Astrocaryum aculeatum*	Y	Y	Least Concern	210	1	210	210	100	0	BRA018	CPATU
Vegetables	*Solanum lycocarpum*	Y	Y	Least Concern	90	4	1	86	95.6	0	BRA003	CENARGEN
Vegetables	*Apium australe*	Y	Y		86	3	1	84	97.7	0	CHL171	SAG
Vegetables	*Hypochaeris incana*		Y		71	1	71	71	100	0	CHL171	SAG
Vegetables	*Ricinodendron heudelotii*		Y	Least Concern	58	2	1	57	98.3	0	KEN023	ICRAF
Vegetables	*Momordica dioica*	Y			57	3	1	55	96.5	0	IND001	NBPGR
Vegetables	*Cleomella serrulata*		Y		39	2	1	38	97.4	0	USA956	OPGC
Vegetables	*Chlorophytum borivilianum*		Y	Critically Endangered	37	1	37	37	100	0	IND001	NBPGR
Vegetables	*Amsinckia tessellata*		Y		36	2	1	35	97.2	40	USA022	W6
Vegetables	*Cardamine bulbifera*		Y		35	1	35	35	100	0	GBR004	RBG
Vegetables	*Helosciadium repens*	Y			35	1	35	35	100	6	DEU502	BOGOS
Vegetables	*Abelmoschus angulosus*	Y		Least Concern	30	1	30	30	100	0	IND001	NBPGR
Vegetables	*Allium rosenorum*	Y			25	1	25	25	100	0	DEU146	IPK
Vegetables	*Suaeda linearis*		Y		25	1	25	25	100	0	MEX263	DNRS
Oil plants	*Astrocaryum vulgare*	Y	Y		263	1	263	263	100	0	BRA018	CPATU
Oil plants	*Allanblackia floribunda*		Y	Least Concern	256	1	256	256	100	0	KEN023	ICRAF
Oil plants	*Attalea speciosa*			Least Concern	172	4	1	168	97.7	0	BRA142	CPAMN
Herbs & spices	*Alpinia officinarum*				73	1	73	73	100	0	VNM049	PRC
Herbs & spices	*Lippia dulcis*		Y		54	1	54	54	100	0	MEX006	BANGEV
Herbs & spices	*Distichlis spicata*		Y	Least Concern	47	2	1	46	97.9	4	USA022	W6
Herbs & spices	*Apium prostratum*	Y	Y		40	2	2	38	95	0	CHL171	SAG
Herbs & spices	*Renealmia aromatica*		Y		40	1	40	40	100	0	MEX006	BANGEV

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Herbs & spices	*Aframomum corrorima*			Least Concern	26	1	26	26	100	0	ETH085	EBI
Herbs & spices	*Crocus autumnalis*	Y			20	1	20	20	100	0	ESP124	CIACU
Pseudo cereals	*Cycas micronesica*			Endangered	23	1	23	23	100	0	USA047	MIA
Stimulants	*Paullinia cupana*				358	2	1	357	99.7	0	BRA027	CPAA
Stimulants	*Ilex guayusa*	Y		Least Concern	161	3	1	157	97.5	0	ECU098	USFQ
Stimulants	*Coffea mauritiana*	Y		Vulnerable	95	3	1	93	97.9	0	FRA254	IRD
Stimulants	*Coffea macrocarpa*	Y		Vulnerable	63	2	2	61	96.8	0	FRA254	IRD
Stimulants	*Cola nitida*			Least Concern	45	2	1	44	97.8	0	KEN023	ICRAF
Stimulants	*Ilex brevicuspis*	Y			32	1	32	32	100	0	ARG1222	EEA INTA Cerro Azul
Stimulants	*Ilex dumosa*	Y			30	1	30	30	100	0	ARG1222	EEA INTA Cerro Azul
Stimulants	*Coffea anthonyi*	Y		Vulnerable	28	1	28	28	100	0	FRA254	IRD
Stimulants	*Ilex theezans*				28	1	28	28	100	0	ARG1222	EEA INTA Cerro Azul
Stimulants	*Coffea myrtifolia*	Y		Endangered	21	1	21	21	100	0	FRA254	IRD
Forages	*Rytidosperma richardsonii*			Least Concern	813	2	2	811	99.8	0	NZL001	AGRESEARCH
Forages	*Rytidosperma bipartitum*				729	2	3	726	99.6	0	NZL001	AGRESEARCH
Forages	*Eriocoma hymenoides*				513	2	5	508	99	45	USA022	W6
Forages	*Leymus mollis*	Y			351	6	1	335	95.4	2	USA022	W6
Forages	*Elymus elymoides*	Y			324	5	1	313	96.6	47	USA022	W6
Forages	*Disakisperma obtusiflorum*				323	5	1	318	98.5	1	KEN212	GeRRI
Forages	*Festuca gracillima*				192	2	3	189	98.4	0	CHL171	SAG
Forages	*Lathyrus nervosus*	Y			190	3	1	185	97.4	0	CHL171	SAG
Forages	*Leucaena trichandra*			Least Concern	183	4	2	174	95.1	26	KEN023	ICRAF
Forages	*Anthosachne rectiseta*				173	2	6	167	96.5	41	USA022	W6
Forages	*Muhlenbergia phleoides*				157	3	1	154	98.1	0	MEX208	CNRG
Forages	*Vicia magellanica*	Y			132	1	132	132	100	0	CHL171	SAG
Forages	*Vigna tenuicaulis*	Y			121	2	1	120	99.2	0	JPN183	NARO
Forages	*Poa arctica*				116	2	3	113	97.4	13	USA022	W6
Forages	*Astragalus filipes*				85	2	1	84	98.8	12	USA022	W6
Forages	*Leucaena salvadorensis*			Near Threatened	82	3	1	78	95.1	0	KEN023	ICRAF
Forages	*Entolasia imbricata*				80	3	1	78	97.5	0	KEN212	GeRRI
Forages	*Bromus cebadilla*				55	1	55	55	100	7	NZL001	AGRESEARCH

(Cont.)

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Forages	*Hyparrhenia papillipes*				55	1	55	55	100	0	KEN212	GeRRI
Forages	*Grayia spinosa*				53	2	1	52	98.1	37	USA022	W6
Forages	*Crepis acuminata*				44	2	1	43	97.7	42	USA022	W6
Forages	*Dactyloctenium geminatum*				39	2	1	38	97.4	8	KEN212	GeRRI
Forages	*Argyrolobium harveyanum*				36	2	1	35	97.2	20	AUS167	APG
Forages	*Sporobolus flexuosus*				34	2	1	33	97.1	15	USA022	W6
Forages	*Medicago lessingii*	Y			33	1	33	33	100	0	GBR004	RBG
Forages	*Muhlenbergia porteri*				33	2	1	32	97	3	USA016	S9
Forages	*Bromus lithobius*				29	1	29	29	100	0	NZL001	AGRESEARCH
Forages	*Nicoraepoa robusta*				29	2	1	28	96.6	4	USA022	W6
Forages	*Piptochaetium stipoides*				27	1	27	27	100	0	URY003	INIA LE
Forages	*Leptochloa crinita*				26	1	26	26	100	0	ARG1351	BGANGUIL
Forages	*Bouteloua uniflora*				24	1	24	24	100	0	MEX208	CNRG
Forages	*Cupressus atlantica*				24	1	24	24	100	0	GBR004	RBG
Forages	*Festuca octoflora*				23	2	1	22	95.7	32	USA022	W6
Forages	*Cenchrus stramineus*			Least Concern	22	2	1	21	95.5	5	KEN212	GeRRI
Forages	*Harpachne schimperi*				21	1	21	21	100	5	KEN212	GeRRI
Forages	*Nassella mucronata*				21	1	21	21	100	0	URY003	INIA LE
Forages	*Sporobolus pumilus*			Least Concern	20	1	20	20	100	5	USA022	W6
Material plants	*Pongamia pinnata*			Least Concern	720	4	1	717	99.6	0	IND001	NBPGR
Material plants	*Populus nigra*			Data Deficient	661	10	1	634	95.9	0	ESP149	CITA-PAM
Material plants	*Hevea brasiliensis*			Least Concern	551	6	1	544	98.7	0	BRA034	CPAC
Material plants	*Pinus elliottii*			Least Concern	436	4	1	429	98.4	0	BRA190	CNPF
Material plants	*Pinus ponderosa*			Least Concern	415	6	1	405	97.6	0	USA476	NSL
Material plants	*Juncus decipiens*			Least Concern	387	1	387	387	100	0	JPN183	NARO
Material plants	*Myracrodruon urundeuva*			Data Deficient	300	2	6	294	98	0	BRA003	CENARGEN
Material plants	*Pinus pungens*			Least Concern	294	2	4	290	98.6	17	USA476	NSL
Material plants	*Pinus pseudostrobus*			Least Concern	288	3	1	286	99.3	0	MEX208	CNRG
Material plants	*Grindelia chiloensis*				182	3	1	178	97.8	0	RUS001	VIR
Material plants	*Pinus hartwegii*			Least Concern	137	3	2	133	97.1	0	MEX208	CNRG

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Material plants	*Pinus greggii*			Vulnerable	121	4	1	117	96.7	0	BRA190	CNPF
Material plants	*Croton megalocarpus*			Least Concern	108	2	1	107	99.1	0	KEN023	ICRAF
Material plants	*Astronium fraxinifolium*				67	2	2	65	97	0	BRA003	CENARGEN
Material plants	*Ocotea porosa*			Vulnerable	61	1	61	61	100	0	BRA190	CNPF
Material plants	*Torreya taxifolia*			Critically Endangered	59	1	59	59	100	0	USA151	NAGU
Material plants	*Agave inaequidens*			Least Concern	41	2	1	40	97.6	0	MEX337	JB-IB-UNAM
Material plants	*Cnidoscolus quercifolius*			Least Concern	38	2	1	37	97.4	0	BRA007	CNPA
Material plants	*Agave durangensis*				35	2	1	34	97.1	0	MEX257	UG
Material plants	*Chaenactis stevioides*				34	2	1	33	97.1	12	USA022	W6
Material plants	*Torminalis glaberrima*				32	1	32	32	100	0	GBR004	RBG
Material plants	*Tsuga chinensis*			Least Concern	28	2	1	27	96.4	0	USA151	NAGU
Material plants	*Magnolia fraseri*			Least Concern	26	1	26	26	100	0	USA151	NAGU
Material plants	*Chrysanthemum japonense*				25	1	25	25	100	0	JPN183	NARO
Material plants	*Agave mapisaga*				22	1	22	22	100	0	MEX257	UG
Material plants	*Albizia boivinii*			Least Concern	20	1	20	20	100	0	GBR004	RBG
Material plants	*Salix atrocinerea*			Least Concern	20	1	20	20	100	0	GBR004	RBG
Medicinal plants	*Tecomella undulata*			Endangered	344	2	3	341	99.1	0	IND001	NBPGR
Medicinal plants	*Adesmia boronioides*				327	3	1	325	99.4	0	CHL171	SAG
Medicinal plants	*Chiliotrichum diffusum*				295	2	2	293	99.3	0	CHL171	SAG
Medicinal plants	*Elwendia persica*				281	3	2	274	97.5	0	IND001	NBPGR
Medicinal plants	*Pfaffia glomerata*				278	2	1	277	99.6	0	BRA003	CENARGEN
Medicinal plants	*Artemisia tridentata*			Least Concern	211	4	2	203	96.2	48	USA022	W6
Medicinal plants	*Azorella prolifera*				176	3	1	174	98.9	0	CHL171	SAG
Medicinal plants	*Glycosmis cochinchinensis*				148	2	1	147	99.3	0	IND001	NBPGR
Medicinal plants	*Heterotheca villosa*				105	2	2	103	98.1	0	USA956	OPGC
Medicinal plants	*Valeriana carnosa*				100	2	1	99	99	0	CHL171	SAG
Medicinal plants	*Carapichea ipecacuanha*				68	1	68	68	100	0	BRA018	CPATU
Medicinal plants	*Plantago patagonica*				66	2	1	65	98.5	20	USA022	W6
Medicinal plants	*Boesenbergia stenophylla*			Critically Endangered	60	1	60	60	100	0	MYS125	UPM
Medicinal plants	*Chaenactis douglasii*				59	2	1	58	98.3	41	USA022	W6
Medicinal plants	*Melaleuca alternifolia*				42	3	1	40	95.2	0	AUS165	AGG

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Medicinal plants	*Trichosanthes bracteata*				39	1	39	39	100	0	IND001	NBPGR
Medicinal plants	*Pectis papposa*				37	2	1	36	97.3	28	USA022	W6
Medicinal plants	*Cupania dentata*			Least Concern	35	2	1	34	97.1	0	MEX006	BANGEV
Medicinal plants	*Mikania laevigata*				34	1	34	34	100	0	BRA003	CENARGEN
Medicinal plants	*Cnidoscolus multilobus*			Least Concern	33	2	1	32	97	0	MEX006	BANGEV
Medicinal plants	*Helicteres isora*				33	1	33	33	100	0	IND001	NBPGR
Medicinal plants	*Tinospora crispa*				29	2	1	28	96.6	0	PHL129	IPB-NPGRL
Medicinal plants	*Phyllanthus tenellus*				28	1	28	28	100	0	BRA003	CENARGEN
Medicinal plants	*Wrightia tinctoria*				28	1	28	28	100	0	IND001	NBPGR
Medicinal plants	*Diervilla lonicera*				27	2	1	26	96.3	46	USA020	NC7
Medicinal plants	*Valeriana jatamansi*				26	1	26	26	100	0	IND001	NBPGR
Medicinal plants	*Antidesma madagascariense*			Least Concern	25	1	25	25	100	0	GBR004	RBG
Medicinal plants	*Solanum subinerme*			Least Concern	24	1	24	24	100	0	BRA003	CENARGEN
Medicinal plants	*Ipomopsis aggregata*				23	2	1	22	95.7	0	USA956	OPGC
Medicinal plants	*Frasera speciosa*				22	2	1	21	95.5	0	USA956	OPGC
Medicinal plants	*Salix aurita*				22	2	1	21	95.5	0	GBR004	RBG
Medicinal plants	*Castilleja linariifolia*				21	2	1	20	95.2	0	USA956	OPGC
Medicinal plants	*Eriodictyon californicum*				20	1	20	20	100	0	USA956	OPGC
Medicinal plants	*Lindera obtusiloba*			Least Concern	20	1	20	20	100	0	USA151	NAGU
Ornamentals	*Araucaria angustifolia*			Critically Endangered	411	2	1	410	99.8	0	BRA190	CNPF
Ornamentals	*Anemone multifida*				384	5	1	372	96.9	0	CHL171	SAG
Ornamentals	*Baccharis patagonica*				158	1	158	158	100	0	CHL171	SAG
Ornamentals	*Senecio candidans*				158	2	1	157	99.4	0	CHL171	SAG
Ornamentals	*Geum magellanicum*				156	1	156	156	100	0	CHL171	SAG
Ornamentals	*Senecio smithii*				106	2	1	105	99.1	0	CHL171	SAG
Ornamentals	*Sisyrinchium patagonicum*				106	1	106	106	100	0	CHL171	SAG
Ornamentals	*Petunia axillaris*				83	3	1	79	95.2	37	DEU146	IPK
Ornamentals	*Rhododendron eriocarpum*				80	3	1	76	95	0	JPN183	NARO
Ornamentals	*Baccharis magellanica*				78	2	2	76	97.4	0	CHL171	SAG
Ornamentals	*Anarthrophyllum desideratum*				77	1	77	77	100	0	CHL171	SAG
Ornamentals	*Begonia fusca*				47	1	47	47	100	0	MEX006	BANGEV
Ornamentals	*Begonia tomentosa*				45	1	45	45	100	7	DEU146	IPK

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Ornamentals	*Xiquexique gounellei*			Least Concern	44	1	44	44	100	0	BRA146	CNPAT
Ornamentals	*Calceolaria herbeohybrida*				41	2	1	40	97.6	0	DEU146	IPK
Ornamentals	*Crocus nevadensis*	Y		Least Concern	40	1	40	40	100	0	ESP124	CIACU
Ornamentals	*Geranium magellanicum*				39	1	39	39	100	0	CHL171	SAG
Ornamentals	*Camellia lutchuensis*			Least Concern	37	2	1	36	97.3	0	JPN183	NARO
Ornamentals	*Fothergilla gardenii*				37	1	37	37	100	0	USA151	NAGU
Ornamentals	*Airampoa soehrensii*				36	1	36	36	100	0	PER006	INIA-EEA.A
Ornamentals	*Ferocactus robustus*			Vulnerable	35	2	1	34	97.1	0	MEX337	JB-IB-UNAM
Ornamentals	*Sinningia speciosa*				35	1	35	35	100	0	DEU146	IPK
Ornamentals	*Oenocarpus minor*				34	1	34	34	100	0	BRA018	CPATU
Ornamentals	*Callitris oblonga*			Vulnerable	30	1	30	30	100	0	GBR004	RBG
Ornamentals	*Liatris pycnostachya*				28	2	1	27	96.4	4	USA956	OPGC
Ornamentals	*Silene conica*				27	2	1	26	96.3	0	GBR004	RBG
Ornamentals	*Dahlia rupicola*				26	2	1	25	96.2	0	MEX131	UDG-CUCBA
Ornamentals	*Pilosocereus pachycladus*			Least Concern	26	2	1	25	96.2	0	BRA146	CNPAT
Ornamentals	*Gazania splendens*				25	1	25	25	100	0	BGR001	IPGR
Ornamentals	*Escallonia virgata*				24	2	1	23	95.8	0	CHL171	SAG
Ornamentals	*Melocactus zehntneri*			Least Concern	24	2	1	23	95.8	0	BRA146	CNPAT
Ornamentals	*Mammillaria mystax*			Least Concern	23	2	1	22	95.7	0	MEX337	JB-IB-UNAM
Ornamentals	*Pilosocereus chrysostele*			Near Threatened	23	1	23	23	100	0	BRA146	CNPAT
Ornamentals	*Pittocaulon praecox*			Least Concern	23	1	23	23	100	0	MEX337	JB-IB-UNAM
Ornamentals	*Ensete perrieri*			Critically Endangered	22	2	1	21	95.5	0	MDG017	FOFIFA CRR-E
Ornamentals	*Nyctocereus serpentinus*				21	2	1	20	95.2	0	MEX337	JB-IB-UNAM
Ornamentals	*Lagenaria abyssinica*	Y			20	1	20	20	100	20	KEN212	GeRRI
Ornamentals	*Quercus canariensis*	Y		Data Deficient	20	1	20	20	100	0	TUN029	BNG
Fibre plants	*Abutilon bidentatum*				40	2	1	39	97.5	0	PAK001	PGRP
Other	*Lepidophyllum cupressiforme*				596	1	596	596	100	0	CHL171	SAG
Other	*Solanum myriacanthum*	Y			212	3	3	204	96.2	0	IND001	NBPGR
Other	*Senecio patagonicus*				183	1	183	183	100	0	CHL171	SAG
Other	*Mulguraea tridens*				155	2	1	154	99.4	0	CHL171	SAG

(Cont.)

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Other	*Perezia recurvata*				141	2	2	139	98.6	0	CHL171	SAG
Other	*Perezia lactucoides*				138	1	138	138	100	0	CHL171	SAG
Other	*Carex banksii*				114	1	114	114	100	0	CHL171	SAG
Other	*Marsippospermum grandiflorum*				109	2	2	107	98.2	0	CHL171	SAG
Other	*Carex darwinii*				98	1	98	98	100	0	CHL171	SAG
Other	*Primula magellanica*				97	2	2	95	97.9	0	CHL171	SAG
Other	*Acaena sericea*				91	1	91	91	100	0	CHL171	SAG
Other	*Gavilea lutea*				91	1	91	91	100	0	CHL171	SAG
Other	*Luzula chilensis*				91	2	1	90	98.9	0	CHL171	SAG
Other	*Nardophyllum bryoides*				83	1	83	83	100	0	CHL171	SAG
Other	*Acaena integerrima*				75	1	75	75	100	0	CHL171	SAG
Other	*Iocenes virens*				75	1	75	75	100	0	CHL171	SAG
Other	*Deguelia urucu*				62	1	62	62	100	0	BRA018	CPATU
Other	*Gamochaeta spiciformis*				54	2	1	53	98.1	0	CHL171	SAG
Other	*Acaena argentea*				52	2	1	51	98.1	0	CHL171	SAG
Other	*Olsynium biflorum*				50	1	50	50	100	0	CHL171	SAG
Other	*Taraxacum taraxacoides*				49	1	49	49	100	0	NZL001	AGRESEARCH
Other	*Ambrosia salsola*				46	2	2	44	95.7	34	USA022	W6
Other	*Epilobium australe*				46	1	46	46	100	0	CHL171	SAG
Other	*Machaeranthera tanacetifolia*				46	2	2	44	95.7	23	USA022	W6
Other	*Senecio darwinii*				46	1	46	46	100	0	CHL171	SAG
Other	*Iva frutescens*				45	2	1	44	97.8	0	USA022	W6
Other	*Chaenactis fremontii*				43	2	2	41	95.3	10	USA022	W6
Other	*Silene magellanica*				42	1	42	42	100	0	CHL171	SAG
Other	*Carya myristiciformis*	Y		Least Concern	41	3	1	39	95.1	0	USA133	BRW
Other	*Chylismia brevipes*				40	2	1	39	97.5	18	USA022	W6
Other	*Heliocarpus donnellsmithii*				39	1	39	39	100	0	MEX006	BANGEV
Other	*Senecio magellanicus*				39	1	39	39	100	0	CHL171	SAG
Other	*Misodendrum punctulatum*				38	1	38	38	100	0	CHL171	SAG
Other	*Ranunculus peduncularis*				37	2	1	36	97.3	0	CHL171	SAG
Other	*Tetroncium magellanicum*				36	2	1	35	97.2	0	CHL171	SAG
Other	*Malacothrix glabrata*				34	2	1	33	97.1	30	USA022	W6
Other	*Artemisia cana*				32	2	1	31	96.9	48	USA022	W6

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Minimum genebank collection size (accessions)	Maximum genebank collection size (accessions)	Maximum genebank collection size (%)	Safety duplication % of the maximum collection	Holding institute code	Holding institute acronym
Other	*Lepidium spicatum*				32	1	32	32	100	0	CHL171	SAG
Other	*Senecio alloeophyllus*				32	1	32	32	100	0	CHL171	SAG
Other	*Senecio kingii*				32	1	32	32	100	0	CHL171	SAG
Other	*Acaena pinnatifida*				30	2	1	29	96.7	0	CHL171	SAG
Other	*Crepis occidentalis*				30	2	1	29	96.7	48	USA022	W6
Other	*Gentianella campestris*				30	1	30	30	100	0	GBR004	RBG
Other	*Discaria chacaye*			Least Concern	28	1	28	28	100	0	CHL171	SAG
Other	*Erigeron pumilus*				28	2	1	27	96.4	37	USA022	W6
Other	*Carex macloviana*				27	2	1	26	96.3	0	CHL171	SAG
Other	*Callitris preissii*			Least Concern	26	1	26	26	100	0	GBR004	RBG
Other	*Cuphea lutescens*				26	2	1	25	96.2	0	BRA003	CENARGEN
Other	*Ajania shiwogiku*				25	1	25	25	100	0	JPN183	NARO
Other	*Erigeron linearis*				24	2	1	23	95.8	30	USA022	W6
Other	*Penstemon pachyphyllus*				24	2	1	23	95.8	30	USA956	OPGC
Other	*Cayaponia laciniosa*				23	1	23	23	100	0	IND001	NBPGR
Other	*Gavilea supralabellata*				23	1	23	23	100	0	CHL171	SAG
Other	*Antennaria chilensis*				22	1	22	22	100	0	CHL171	SAG
Other	*Artemisia arbuscula*				22	2	1	21	95.5	33	USA022	W6
Other	*Carex depauperate*				21	1	21	21	100	0	GBR004	RBG
Other	*Hieracium hanburyi*				21	1	21	21	100	0	GBR004	RBG
Other	*Leucheria purpurea*				21	1	21	21	100	0	CHL171	SAG
Other	*Stenotus acaulis*				21	2	1	20	95.2	40	USA022	W6
Other	*Chaenactis carphoclinia*				20	1	20	20	100	0	USA022	W6

Appendix 4

A summary of crop gene pool-specific gaps listed in published crop strategies

The global strategies for the long-term conservation and use of crop-specific gene pools offer a source of information on current gaps in crop collections of global importance. Selected extracts and/or summaries of the strategies and of other relevant available resources are provided below. For a full list of published Global Crop Conservation Strategies, see Crop Trust (2024). It should be noted that some information from the older publications (years of publication are given in the embedded references) may be slightly outdated.

Apples. "Many wild species (or key populations of wild species) are under-represented in current collections. These gaps should be precisely identified and filled. Wild *Malus* species could be represented as exemplar accessions in grafted field plantings, as orchards of seedlings, as seeds, as pollen, or any combination of these. Field collections of wild species should also be maintained (to some degree) for immediate use in breeding programmes or for evaluation of desirable novel alleles and traits." (Bramel and Volk, 2019, p. 34)

Barley. "Natural populations of the wild progenitor of barley, *Hordeum vulgare* subsp. *spontaneum* and other wild relatives are endangered because of habitat lost by overgrazing, changes in land use and other negative human-induced activities. Landraces are gradually being replaced with improved germplasm, but they are still grown in low-input farming systems, particularly in marginal and stress-affected areas." (Crop Trust, 2008a, p. 39).

Beans. For cultivated *Phaselolus vulgaris*, landraces from the Colombian, Peruvian and Venezuelan Andes are not well represented in genebanks (Debouck, 2014). Similarly, Ramirez-Villegas *et al.* (2020) in a recent gap analysis identified Chile, Colombia, Peru and the Bolivarian Republic of Venezuela as priorities for the collection of landraces of the Andean gene pool, and Belize, Guatemala and Mexico for collection of landraces belonging to the Mesoamerican gene pool.

For cultivated lima bean, year-bean and tepary bean germplasm resources not yet conserved *ex situ*, there are places worth exploring in Central America. Non-commercial cultivated types of lima beans are still worth collecting in Brazil, Colombia, Paraguay, Peru and the Bolivarian Republic of Venezuela. Germplasm of lima beans found in the distribution range in Africa and Asia might still be under-represented in genebanks. Regarding bean wild relatives, the gap is comparatively small for wild *P. vulgaris* (i.e. in Oaxaca [Mexico], Panama, the Bolivarian Republic of Venezuela, the Plurinational State of Bolivia, and central western Argentina).

While wild *P. lunatus* has been relatively well collected in Costa Rica, Ecuador, Mexico and Peru, additional collecting needs to be conducted in lowland South America, from the Bolivarian Republic of Venezuela down to Argentina, and in the Caribbean (Debouck, 2014). Gap filling is required in the Bolivarian Republic of Venezuela for wild *P. lunatus*, weedy *P. dumosus* and wild *P. vulgaris*. "Wild teparies should be sampled towards the southeast, in Mexico and Central

America. The sampling of wild *P. coccineus* has been irregular. The secondary gene pools of the five bean cultigens would need additional collecting work, possibly, with the exceptions of *P. dumosus* and *P. costaricensis* in Guatemala and Costa Rica, respectively (Ramírez-Villegas *et al*., 2020; Araya-Villalobos et al. 2001). One should note that the gene pool of Lima bean is the largest in the genus, with good *ex situ* representation of the secondary genepool only from the Andes" (Debouck, 2014, p. 42).

Brassica. An assessment of the *Brassica* species conserved *ex situ* found that some species are not represented in global collections and others of conservation significance (*B. hilarionis* and *B. drepanensis*) are poorly represented (Allender and Giovannini, 2023). Castillo-Lorenzo *et al.* (2024) found 787 *Brassica* species not yet conserved *ex situ*, and more than 200 that are under-represented. Kazakhstan and Türkiye were the countries with the greatest number of taxa missing from *ex situ* collections (Castillo-Lorenzo *et al*., 2024).

Breadfruit. The National Tropical Botanical Garden, with its Breadfruit Institute in Kahanu Garden, Maui, Hawaii, United States, manages the largest and most unique breadfruit collection globally (Crop Trust, 2007a). To fill existing gaps, the following materials still require collection:

- "*A. altilis* from Solomon Islands, Vanuatu, Fiji and the Caribbean Islands;
- *A. altilis x A. mariannensis* from Chuuk and Kosrae, the Federated States of Micronesia, the Marshall Islands, Palau and Tuvalu;
- *A mariannensis* from Palau, Guam and the Mariana Islands" (Crop Trust, 2007a, p12).

Cacao. Wild populations of *Theobroma cacao* should be collected in Brazil, Colombia, French Guiana, Guyana, Suriname and the Bolivarian Republic of Venezuela. Cacao landraces should be collected in Honduras, Nicaragua, the Lesser Antilles, the Orinoco delta and the Colombian Pacific coast. Wild *Theobroma* and *Herrania* species are also under-represented in *ex situ* collections (CacaoNet, 2012).

Capsicum. The *Global strategy for the conservation and use of Capsicum genetic resources* (Barchenger and Khoury, 2022) found that *Capsicum annum* var. *annum* from the following regions/countries is under-represented in *ex situ* collections: Western and Middle Africa, Southern Asia (Bhutan, Nepal), South-eastern Asia (Cambodia, the Lao People's Democratic Republic and Myanmar), South America (Chile, Paraguay, Suriname and the Bolivarian Republic of Venezuela) (Barchenger and Khoury, 2022).

For *C. chinense*, Middle Africa and Western Africa, South-eastern Asia, Eastern Asia and Oceania are not well represented in genebanks. For *C. frutescens*, South-eastern Asia, Cambodia, Indonesia and Myanmar are under-represented. For *C. pubescens*, Colombia, Ecuador, Mexico, the Plurinational State of Bolivia and Central America are not well represented in *ex situ* collections.

A conservation gap analysis for *Capsicum* wild species found that 35 taxa are high priority for collecting and 23 of these are not conserved *ex situ* (Khoury *et al*., 2019).

Cassava. According to the publication *A global conservation strategy for cassava and wild* Manihot *species*, close to 15 000 distinct landraces "should be conserved *ex situ* to adequately represent global genetic diversity of cassava" (Hershey, 2010, p. 41). About two-thirds of this goal has already been reached (Hershey, 2010). The remaining priority countries are: the Plurinational State of Bolivia, Brazil, Colombia, the Democratic Republic of the Congo, Haiti, Mozambique, Nicaragua, Peru, Uganda, the United Republic of Tanzania and the Bolivarian Republic of Venezuela (Hershey, 2010). Countries that need to be better represented in the international centres are: Brazil, the Congo, Côte d'Ivoire, the Democratic Republic of the Congo, Malawi, Mozambique, Peru, Rwanda, Uganda and the United Republic of Tanzania. The strategy includes a table with information on wild species of concern that are not represented in any *ex situ* collection.

Chickpea. The global collection of wild annual *Cicer* species covers only a subset of the diversity available in wild populations (Crop Trust, 2008b). Hence, additional collecting should be undertaken to fill the gaps for wild species, i.e. "the putative progenitor (*C. reticulatum*), which together with *C. echinospermum* belongs to the primary genepool of the cultigen (Crop Trust, 2008b). From the secondary genepool, *C. bijugum* is a priority for collectio. These species are distributed mainly in west, south and southeastern Türkiye, northern Iraq and northeastern parts of the Islamic Republic of Iran). Other priority species include *C. cuneatum* in Ethiopia and wild species in general in Pakistan".

"The following geographical areas were identified as under-represented in germplasm collections with respect to landraces of *C. arietinum*: Hindhu Kush-Himalayan region (India, Pakistan, Afghanistan and Nepal), west and north China, Ethiopia (Desi chickpea), Uzbekistan, Armenia and Georgia" (Crop Trust, 2008b, p. 19).

Coconut. The *Global Strategy for the Conservation and Use of Coconut Genetic Resources* 2018–2028 (COGENT, 2017) set a goal of collecting up to 500 well-chosen populations or varieties between 2018 and 2028. These should include compact dwarfs, and tall-type varieties or populations. Populations with putative pest and disease resistance are also targeted for collecting. Geographically, the priorities for collecting are: Latin America, Caribbean and Africa and remote small islands.

Coffee. Gaps identified in coffee collections were "Mascarocoffea species, domesticated coffee from Yemen and leaf rust differentials" (Bramel *et al*., 2017, p. 22). *C. racemosa*, *C. rhamnifolia*, *C. pseudozanguebariae*, *C. fadenii*, *C. eugenioides* need to be collected in Kenya, *C. brassii* in Papua New Guinea, *Psilanthus* species in India, *C. iberica*, *C. stenophylla* and *C. humilis* in Côte d'Ivoire (Bramel *et al*., 2017). Further collecting of coffee wild relatives should also be conducted in the Ethiopia and French Island of Réunion (Bramel *et al*., 2017).

Cucurbits. Overall, "for many cucurbit crops, the existing *ex situ* gene pool may be limited with regard to both the short-term and the long-term needs of breeding programmes, which continually face new" challenges from diseases and insect pests and abiotic stress (Ebert *et al*., 2023, p. 79). "It is important to address collection needs for wild relatives in the Americas, Africa and Asia; [and] for landraces in primary regions of diversity (e.g. Mexico and sub-Saharan Africa), as well as in other regions with unique diversity (e.g. Bangladesh, China, and Myanmar)" (Ebert *et al*., 2023, p. 79). Collections should be prioritized in extreme environments to capture abiotic stress tolerance and in areas with high pest and disease pressure to identify genotypes that present single or multiple resistance (Ebert *et al*., 2023).

More specifically, gaps identified in Ebert *et al*. (2023) by cucurbit crops are:

Citrullus: "North Africa, West Africa, Central and East Africa, and South America should be targeted for additional collecting" (Ebert *et al*., 2023, p. 7) *C. ecirrhosus*, *C. rehmii,* and *C. naudinianus* are not well represented in *ex situ* collections (Ebert *et al.*, 2023).

Cucurbita: "Among *Cucurbita* crop wild relatives (CWR), *C. cordata*, *C. pedatifolia*, *C. radicans* and *C. x scabridifolia* are high priority for further collecting, followed by *C. digitata*, *C. foetidissima* and *C. palmata*" (Ebert *et al*., 2023, p. 7). The maps of the modelled distributions and of the gaps of *Cucurbita* wild species are freely available in the supporting information of Khoury *et al*. (2020)" (Ebert *et al*., 2023, p. 48).

For *Cucurbita argyrosperma* subsp *argyrosperma*, further collecting of landraces in Central America should be a priority. For *C. moschata*, germplasm from Colombia is under-represented *ex situ*. "Generally, the primary centre of diversity (Mexico, Central America and northern South America) is better represented *ex situ* than secondary centres of diversity" (Asia) (Ebert *et al.*, 2023, p. 7).

Cucumis: "Cucumis anguria and *C. metuliferus* have relatively low numbers of accessions conserved *ex situ.* Germplasm of African origin for *C. melo* and *C. sativus* is under-represented in *ex situ* collections. Furthermore, there are no records of accessions for *C. picrocarpus*, the closest CWR of *C. melo."* (Ebert *et al.*, 2023, p. 7).

Gourds (*Benincasa hispida, Cucurbita moschata*, *Lagenaria* spp., *Luffa* spp. and *Momordica* spp.): "The main focus should be on collecting landraces in Bangladesh, Myanmar and Viet Nam." (Ebert *et al.*, 2023, p. 53).

Eggplants. Among the 18 priority taxa of eggplant wild relatives, the following were found to have fewer than 50 accessions conserved *ex situ*: *Solanum linnaeanum*, *S. asperolanatum*, *S. cumingii*, *S. lidii*, *S. marginatum*, *S. rubetorum* and *S. tomentosum* (Solberg *et al.*, 2022). Regions of domestication that are not well represented in *ex situ* collections should be targeted for further collecting of landraces. Africa and Southern and Eastern Asia were identified as priority regions for further collecting.

Faba bean. Experts identified the following geographical areas as being under-represented in *ex situ* collections of *V. faba*: North Africa (especially the Sudan), Egypt-oasis population, South America, and China. Further collections should also target the following traits: chocolate spot resistance, necrotic yellow virus resistance, heat tolerance, early flowering, *Orobranche* spp. resistance, *Ascochyta* spp. resistance, and leaf miner resistance (Crop Trust, 2009).

The collecting and conservation of *Vicia* subgenus *Vicia* germplasm by international and national forage legume conservation programmes should be a primary focus in order to supplement previously collected materials (Maxted, 1995). Furthermore, national plant genetic resources for food and agriculture (PGRFA) institutes "should be encouraged to undertake targeted collecting and to activate conservation programmes for endemic wild species and landrace material of *V. faba* subsp. *paucijuga*, *V. narbonensis* and *V. sativa*. Species identified as in primary need for monitoring and possible future conservation action include *V. galilaea* (Northern Israel and Western Turkey), *V. sativa* subsp. *devia* (endemic of Brazil), and *V. pyrenaica* (French and Spanish alpine regions)" (Crop Trust, 2009, p. 24).

Grass pea. According to Crop Trust (2007b), an accurate assessment of the gaps in the genetic diversity among existing collections around the globe is not yet available. This would require the complete "geo-referencing of all existing accessions and mapping this information against data on the distribution of producing areas of the crop and on the distribution of wild *Lathyrus* species" (Crop Trust, 2007b, p. 11). Based on expert knowledge, the following geographical gaps have been identified: Russian Federation (Black Sea Coast and Volga-Kama region), Iraq (Kurdish area), Bangladesh (high altitude area of Syleth), India (Northeast and Eastern parts), Ethiopia (high altitude areas), Afghanistan (northeast and central parts), Spain (Almeria [Andalucia] and Murcia). Species-specific gaps exist for *L. sativus* and *L. cicera* in Egypt, Iraq, and the Islamic Republic of Iran, for *L. cicera* and *L. ochrus* in Tunisia, and for *L. ochrus* in Greece and Türkiye (Crop Trust, 2007b).

Lentil. Landraces in China and Morocco are potentially under-represented in germplasm collections around the globe (Crop Trust, 2008c). Gaps are evident in CWR of *Lens* germplasm holdings, especially from Northern African countries such as Algeria, Libya, the Sudan and Tunisia. CWR taxa are also under-represented from the central and west Asian republics of the former Soviet Union. Overall, the collection priority for the wild species remains in southwest

Türkiye, specifically the provinces of Burdur, Isparta and Afyon.

Maize. Portions of the Amazon basin, parts of Central America, and waxy maize in South-eastern Asia have not been collected (Crop Trust, 2007c). Collections from Dominica were completely lost. Public and private tropical inbred lines and important hybrids are not well represented in *ex situ* collections.

"National or international reserves need to be established to protect the remaining fragments of the Balsas, Guatemala, Huehuetenango, and Nicaraguan races of teosinte.[..] *In situ* monitoring of *Tripsacum* populations is recommended in Mexico and Guatemala, the centre of diversity for the genus, and in other countries in Central and South America, where both widespread and endemic species are found. *Ex situ Tripsacum* gardens at CIMMYT and the USDA in Florida should be enriched with the diversity found in *in situ*" (Crop Trust, 2007c, p. 22).

Millets. The finger millet and the pearl millet gene pool were divided hierarchically in groups to stratify the crop diversity within these gene pools. For each crop gene pool, the number of accessions conserved *ex situ* was matched to these groups. A detailed summary of the results of this analysis is found in the updated strategy for the conservation of selected millets (Bramel, Giovannini and Dulloo, 2022).

A spatial gap analysis was conducted for pearl millet and finger millet landraces (Ramirez-Villegas *et al*., 2022) and a summary of the results and maps of the geographical gaps can be found in Bramel, Giovannini and Dulloo (2022).

Musa. Several *Musa* wild species are not well represented in *ex situ* collections (MusaNet, 2016). "A short-term strategy for capturing the *Musa* wild species diversity of particular value for breeding would focus on *M. acuminata* and *M. balbisiana*, with special attention for pest and disease resistance and for favourable agronomic features" (Musanet, 2016, p. 61).

Collecting missions should be undertaken to Myanmar, the extreme north of India, Indonesian New Guinea, Eastern Africa and Papua New Guinea and the Solomon Islands. A long-term strategy would include other species in the Eumusa and Rhodochlamys sections and beyond (e.g. sections Australimusa and Callimusa) (MusaNet, 2016). A more recent conservation status assessment of banana CWR (Mertens *et al.*, 2021) found that 56 out of the 59 species assessed are insufficiently conserved *ex situ.*

Further collecting of Feí banana is recommended in the Lousiade Archipelago in the Pacific and nearby areas. Maoli-Popo'ulu-like cultivars in Pohnpei, the Federated States of Micronesia and Tongan Maoli/Popoulu diversity also need collecting (MusaNet, 2016).

Several collecting missions were conducted after the publication of the global strategy for the conservation and use of *Musa* genetic resources (Van den Houwe *et al*., 2020; Sardos *et al*., 2019a; Sardos *et al*., 2019b).

Oats. Gaps in species coverage exist in most *ex situ* collections (BAZ, 2008). Other gaps include insufficient species-specific population representation and insufficient ecological representation of the species. The low representation of germplasm from Central Asia in the World Base Collection (held by Plant Gene Resources of Canada) is considered a gap. Moreover, there is poor representation of *Avena macrostachya, A. ventricosa, A. damascena, A. atlantica, A. agadiriana, A. murphyi, A. trichophylla, A. matritensis* and *A. insularis* in the World Base Collection. Priorities in gap filling should focus on botanical (species, morphological groups) and geographical completeness.

Pea. The *Global Strategy for the Conservation and Use of Pea Genetic Resources* (Ambrose *et al.*, 2023) recommends further collecting of pea landraces "from Azerbaijan and Turkmenistan in the Caucasus; South-eastern Asia; the Islamic Republic of Iran in western Asia; South Africa, Kenya and Malawi in Africa; Iraq, Israel, Jordan, Lebanon and Palestine in the Near East; and Estonia, Lithuania, Finland, Norway and Belarus in Europe." For pea wild relatives, the strategy recommends prioritizing further collecting of *Pisum elatius* in Northern Africa, Jordan and the Islamic Republic of Iran. Türkiye is a priority for further collecting of *P. fulvum*. The strategy also highlights the need to improve passport data of pea accessions to improve the accuracy of gap analysis results.

Peanut. The *Global Strategy for the Conservation and Use of Peanut Genetic Resources* (Williams, 2022) assesses gaps in *ex situ* collections for wild *Arachis* species and peanut landrace accessions. "The majority of known wild *Arachis* species have germplasm conserved *ex situ [..]*. However, a large number of wild *Arachis* accessions remain unidentified, and many species are represented by only a single or only a very few original germplasm accessions" (Williams, 2022, p. 22). Collecting additional populations of key *Arachis* species, particularly those in the section *Arachis*, is a priority (Williams, 2022).

"Large gaps exist in several *ex situ* collections with regard to the existing diversity of cultivated peanut landraces, which remain poorly studied or conserved in many countries" (Williams, 2022, p. 48). This is the case "in several countries within the peanut's South and Central American range of prehistoric distribution, as well as in some African and Asian countries where locally adapted landraces have not been sufficiently conserved *ex situ"* (Williams, 2022, p. 48). Peanut landraces from Central American and Caribbean countries, from northern South America and Amazonian Brazil, are poorly represented in *ex situ* collections (Williams, 2022). In Africa, landraces from Sierra Leone, Rwanda and Burundi are not well represented in *ex situ* collections. In Asia, landraces from Bangladesh, Malaysia, Myanmar, Nepal, the Philippines, Sri Lanka and Viet Nam appear to be under-represented in genebanks. Further effort is also needed to collect unique landraces from Pakistan and Thailand and from the Pacific Islands of Oceania.

Potato. A gap analysis conducted by Castañeda-Álvarez *et al*. (2016) identified 32 species of potato wild relatives with large gaps in *ex situ* collections. Four of these are endemic in Mexico, three in the Plurinational State of Bolivia, two in Colombia, two in Ecuador and 21 in Peru. The species complete list is available in Table 3.2.1 of the 2022 *Global Strategy for the Conservation of Potato* (Nagel *et al*., 2022). A spatial gap analysis was conducted to identify gaps in collections of potato landraces (Ramirez-Villegas *et al*., 2022). The results show that potato landraces in collections cover 73 percent of the area where they are cultivated, and a summary of the results and maps of the geographical gaps can be found in Nagel *et al.* (2022). Additionally, the composition of the International Potato Center (CIP) collection was analysed by assigning the accessions of the *Solanum tuberosum "Andigenum* group" to the groups corresponding to a hierarchical stratification of the potato gene pool. Based on the results from these analyses they recommend collecting missions in the Plurinational State of Bolivia, in particular in the Tarija and Santa Cruz departments; Ecuador, in the provinces of Pichincha, Napo, Tungurahua and Zamora-Chinchipe; and Peru, in the departments of Arequipa, Moquegua, Piura, San Martin and Tacna. Landraces from Chile and Paraguay must also be considered for further collecting.

Sorghum. Extensive ecosampling of the wild progenitors and landraces of *Sorghum bicolor* in each of the primary, secondary and tertiary centres of diversity of the species was proposed in the 2007 *Strategy for the Global Ex Situ Conservation of Sorghum Genetic resources* (Crop Trust, 2007d). In terms of geographical coverage of the *ex situ* collections, gaps in Western and Middle Africa and in South Sudan identified in 2007 were still to be filled in 2022 (Bramel, Kresovich and Giovannini, 2022). There are also significant gaps in Central America, Central Asia and the Caucasus. Species coverage and ecological sampling at the national level are also considered inadequate (Bramel, Kresovich and Giovannini, 2022).

Myrans *et al*. (2020) assessed the conservation status of wild *Sorghum* taxa both *ex situ* and *in situ*. According to their results, three taxa were categorized as high priority for further conservation and 19 as medium priority. Given the presence of the primary gene pool species *S. bicolor* subsp. *verticilliflorum* in Africa and *S. propinquum* in Asia, it is important to focus on further *ex situ Sorghum* conservation efforts in these regions (Myrans *et al*., 2020).

Sunflower. Extensive collecting of *Helianthus* species in Mexico is a priority (Drummond *et al*., 2023). Collecting *Helianthus annuus* in Canada is also a priority. Other priorities for collecting are *Helianthus inexpectatus*, *H. carnosus*, *H. × multiflorus*, *H. arizonensis*, *H. verticillatus*, and *H.* × doronicoides, *H. agrestis* and *H. glaucophyllus.* These species have a small distribution, an alarming conservation status and a small number of accessions conserved in genebanks.

Sweet potato. The closest wild relatives of sweet potato are 14 species occurring from the central United States to Argentina (Khoury *et al*., 2015). These sweet potato CWR are highly under-represented in *ex situ* conservation and about 80 percent of the species have been identified as being of high priority for further collecting. This list of high-priority species includes species with very few germplasm accessions in open online information systems accessible to the global research community, such as *I. cynanchifolia, I. littoralis, I. tenuissima, I. tabascana, I. lacunosa, I. leucantha, I. splendor-sylvae*, and wild forms of the crop conspecific *I. batatas*. Sweet potato CWR hotspots are found from central Mexico to Central America, and in the extreme southeastern United State.

Temperate forages. Collection gaps are recognized as an ongoing problem. However, among the experts consulted there is general agreement that a better understanding of the scope of existing *ex situ* collections is first needed. This means prioritizing a collective effort at the global scale to better characterize existing collections, address gaps in passport data and identify redundant duplication. This work is seen as necessary before starting new collection activities to fill gaps (Dodd, 2021).

Tea. The primary focus for long-term conservation of tea genetic resources should be the centre of genetic diversity of all botanical varieties of *Camellia sinensis* as well as the respective CWR located in south and southwest China, northeast India and in the northern border areas of Myanmar, Thailand and Viet Nam, adjacent to China. The secondary focus for long-term conservation should be the genetic diversity still existing in old tea germplasm gardens in tea-producing countries around the world. In these gardens, the diversity is based on recombinant populations derived from different seed sources and hybridization events that occurred "during the early establishment of tea production in China, Japan, Korea, India, Sri Lanka, Malawi, Kenya, Madagascar and Indonesia" (Bramel and Chen, 2019).

Vanilla. Bramel and Frey (2021) identified 61 *Vanilla* species not conserved *ex situ* and concluded that most *Vanilla* species are not securely conserved in *ex situ* collections. *V. planifolia*, the most important cultivated vanilla species, is included in the *Vanilla* species at risk of genetic erosion or extinction. The priority gaps are Central and South American species, as these are under-represented in *ex situ* collections. A comprehensive assessment of the conservation of wild *Vanilla* species can be found in CIAT (2020).

***Vigna* crops.** van Zonneveld *et al.* (2020) identified taxa and regions that are priorities for collecting. Their findings are summarized in the 2023 *Global Strategy for the Conservation and Use of* Vigna (Nair *et al*., 2023). The strategy also includes an overview of the number of accessions of cowpea and Bambara groundnut conserved in genebanks by countries and regions where they were collected to identify gaps and underrepresented regions (Nair *et al*., 2023).

Wheat, rye and triticale. The 2007 *Global Strategy for the Ex Situ Conservation with Enhanced Access to Wheat, Rye, and Triticale Genetic Resources* (CIMMYT, 2007) states that the global network of wheat collections will establish priorities for identifying and filling gaps in existing wheat collections for three classes of material: (i) Farmers' varieties/landraces: in parts of Eastern Europe, Western Asia and Northern Africa, the Arabian Peninsula and the Andean highlands, such materials probably still exist in the field. However, these are poorly represented in genebanks and are of high priority for further collecting; (ii) Wild relatives: the level of genetic diversity and the geographic coverage of these species in *ex situ* collections is small. However, more and more wild species are threatened as a result of land-use change and samples of wild species are needed for research projects and breeding purposes. This has increased the need to increase the genetic diversity of wheat CWR held in collections; and (iii) Cultivars: As cultivars are more thoroughly characterized and also evaluated, they possess a higher short-term value for immediate use in wheat breeding.

In collaboration with regional networks, a programme of targeted rye collecting should be developed to fill the gaps in existing rye collections.

In 2016, a study on global conservation priorities for CWR (Castañeda-Álvarez *et al.* 2016) found that wheat wild relatives are fairly well represented in genebanks. A gap analysis conducted by the CGIAR Genebank Platform in 2020 found gaps of durum wheat landraces from arid areas of Chad, Libya, Mali, Mauritania, the Niger and the Sudan, as well as *Triticum aestivum* subsp. *tibeticum* and *T. aestivum* subsp. *yunnanense* from China. The CGIAR Genebank Platform also found gaps in the coverage of the geographical distribution of wild and domesticated emmer wheat (Guzzon *et al.,* 2022).

Yam. *Dioscorea alata* has a large area of distribution ranging from India to China to Melanesia, and many cultivars are not conserved in existing collections (Lebot and Dulloo, 2021). There are no reported *ex situ* collections for *D. alata* in Bangladesh, Cambodia, China, the Lao People's Democratic Republic, Myanmar or Thailand. There is a need for better geographic coverage, but this would involve the transfer of accessions to a certified laboratory and the development of complex sanitation techniques to remove all viruses present. In addition, legal issues regarding the ownership of the cultivars would emerge. Rationalization and downsizing of the existing collections is recommended before launching new collecting trips. Priority should be given to female tetraploids. For *D. cayenensis* and *D. rotundata*, Cameroon and Ethiopia have already been identified for further collecting, but the Central African Republic and South Sudan should also be included. Other gaps in *ex situ* collections are: *D. nummularia* in Indonesia, Papua New Guinea, Solomon Islands and Vanuatu; and *D. oppositifolia* and *D. japonica* cultivars in China, Japan and Taiwan Province of China. For yam CWR, better documentation, taxonomic clarification and review are needed before new samples of CWR are collected. *D. trifida* needs further collecting in northern Brazil and in French Guiana, Guyana and Suriname.

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Appendix 5

Acronyms and institution codes of the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture

These are additional abbreviations mentioned only in Tables 3.5 and 3.19 and Appendices 2 and 3.

Acronyms	Names
AARI (TUR001)	Plant Genetic Resources Department, Aegean Agricultural Research Institute (Türkiye)
ABSC (ARM059)	Agrobiotechnology Scientific Center (Armenia)
AGG (AUS165)	Australian Grains Genebank, Agriculture Victoria (Australia)
AGRESEARCH (NZL001)	Margot Forde Forage Germplasm Centre, AgResearch Ltd (New Zealand)
AGROSAVIA (COL004)	Centro de Investigaciones de Palmira, Corporación Colombiana de Investigación Agropecuaria (Colombia)
AGROSAVIA (COL017)	Corporación Colombiana de Investigación Agropecuaria, AGROSAVIA (Colombia)
AGROSAVIA (COL032)	Centro de Investigación La Suiza, Corporación Colombiana de Investigación Agropecuaria (Colombia)
AGROSAVIA (COL096)	Centro de Investigación El Mira, Corporación Colombiana de Investigación Agropecuaria (Colombia)
Agroscope Changins (CHE001)	Agroscope Changins (Switzerland)
Agroscope Pully (CHE019)	Agroscope Pully (Switzerland)
AiZFwB (POL103)	Arboretum i Zakład Fizjografii w Bolestraszycach (Poland)
APG (AUS167)	Australian Pastures Genebank (Australia)
ARC (SDN002)	Agricultural Plant Genetic Resources Conservation and Research Centre (Sudan)
Asociación ANDES (PER867)	Asociación para la Naturaleza y el Desarrollo Sostenible (Peru)
AVRDC (TWN001)	World Vegetable Center
BAGENO (MEX287)	Banco de Germoplasma de Especies Nativas de Oaxaca (Mexi-co)
BAL (ARG1347)	Banco Activo de Germoplasma de Papa, Forrajeras y Girasol Silvestre (Argentina)
BANGEV (MEX006)	Banco Nacional de Germoplasma Vegetal, Universidad Autónoma de Chapingo (Mexico)
BARI (BGD003)	Bangladesh Agricultural Research Institute (Bangladesh)
BBC-INTA (ARG1342)	Banco Base de Germoplasma, Instituto de Recursos Biológicos, Instituto Nacional de Tecnología Agropecuaria (Argentina)
BGANGUIL (ARG1351)	Banco Activo de Germoplasma de Anguil, Instituto Nacional de Tecnología Agropecuaria (Argentina)

(Cont.)

Acronyms	Names
BGLACONSULTA (ARG1350)	Banco Activo de Germoplasma de La Consulta, Instituto Nacional de Tecnología Agropecuaria (Argentina)
BGMANFREDI (ARG1348)	Banco Activo de Germoplasma de Manfredi, Instituto Nacional de Tecnología Agropecuaria (Argentina)
BGUPV (ESP026)	Generalidad Valenciana. Universidad Politécnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma (Spain)
BJRI (BGD001)	Bangladesh Jute Research Institute (Bangladesh)
BNG (TUN029)	Banque Nationale de Gènes de Tunisie (Tunisia)
BOGOS (DEU502)	Botanical Garden of the University of Osnabrück (Germany)
BPGV-INIAV (PRT001)	Banco Português de Germoplasma Vegetal (Portugal)
BPI-DNCRDC (PHL024)	Bureau of Plant Industry-Davao National Crop Research and Development Center (Philippines)
BRGV Suceava (ROM007)	Suceava Genebank, Academy of Agricultural and Forestry Sciences Bucharest (Romania)
BRRI (BGD002)	Bangladesh Rice Research Institute (Bangladesh)
BRW (USA133)	Pecan Breeding & Genetics, National Germplasm Repository - Brownwood, USDA-ARS (United States)
BSA (DEU101)	Federal Plant Variety Office (Bundessortenamt) (Germany)
BSRI (BGD015)	Bangladesh Sugarcrop Research Institute (BSRI) (Bangladesh)
BTRI (BGD012)	Bangladesh Tea Research Institute (Bangladesh)
CAC (ESP222)	Centro Agrario El Chaparillo (Spain)
CATIE (CRI085)	CATIE - Banco de Germoplasma (Colecciones Semillas Ortodo-xas)
CATIE (CRI134)	CATIE - Jardín Botánico y Colecciones
CATIE (CRI142)	CATIE - Colección Internacional de Cacao
CCGB (CAN025)	Canadian Clonal Genebank, Harrow Research and Development Centre (Canada)
CENARGEN (BRA003)	Embrapa Recursos Genéticos e Biotecnologia (Brazil)
CENICAÑA (COL115)	Centro de investigación de la caña de azúcar (Colombia)
CENTA (SLV050)	Centro Nacional de Tecnología Agropecuaria y Forestal (El Salvador)
CePaCT (FJI049)	Centre for Pacific Crops and Trees
CERI (MEX020)	Campo Experimental Rosario Izapa, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexico)
CGN (NLD037)	Centre for Genetic Resources, Netherlands (Kingdom of the)
CIACU (ESP124)	Junta de Comunidades de Castilla-La Mancha. Consejería de Agricultura. Centro de Investigación Agraria de Albaladejito (Spain)
CICTAMEX (MEX121)	Fundación Salvador Sánchez Colín, Centro de Investigaciones Científicas y Tecnológicas del Aguacate en el Estado de México (Mexico)
CIP (PER001)	International Potato Center
CIRAD (FRA014)	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CIRAD (GUF001)	Campus Agronomie, CIRAD (French Guiana)
CIRAD-FLHOR (FRA201)	Station de la Guadeloupe, CIRAD-FLHOR (France)
CITA-HOR (ESP027)	Gobierno de Aragón. Centro de Investigación y Tecnología Agroalimentaria. Banco de Germoplasma de Hortícolas (Spain)
CITA-PAM (ESP149)	Gobierno de Aragón. Centro de Investigación y Tecnología Agroalimentaria. Recursos Forestales (Spain)
CNPA (BRA007)	Embrapa Algodão (Brazil)
CNPAF (BRA008)	Embrapa Arroz e Feijão (Brazil)
CNPAT (BRA146)	Embrapa Agroindústria Tropical (Brazil)
CNPF (BRA190)	Embrapa Florestas (Brazil)

Acronyms	Names
CNPH (BRA012)	Embrapa Hortaliças (Brazil)
CNPMF (BRA004)	Embrapa Mandioca e Fruticultura Tropical (Brazil)
CNPSO (BRA014)	Embrapa Soja (Brazil)
CNPT (BRA015)	Embrapa Trigo (Brazil)
CNPUV (BRA141)	Embrapa Uva e Vinho (Brazil)
CNRG (MEX208)	Centro Nacional de Recursos Genéticos, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexico)
COR (USA026)	National Clonal Germplasm Repository USDA, ARS (United States)
CORBANA (CRI011)	Corporación Bananera Nacional S.A. (Costa Rica)
COT (USA049)	Crop Germplasm Research Unit USDA, ARS (United States)
CPAA (BRA027)	Embrapa Amazônia Ocidental (Brazil)
CPAC (BRA034)	Embrapa Cerrados (Brazil)
CPACT/EMBRAPA (BRA020)	Embrapa Clima Temperado (Brazil)
CPAFAP (BRA239)	Embrapa Amapá (Brazil)
CPAMN (BRA142)	Embrapa Meio Norte (Brazil)
CPATSA (BRA017)	Embrapa Semi-Árido (Brazil)
CPATU (BRA018)	Embrapa Amazônia Oriental (Brazil)
CRA-L (TGO031)	Centre de Recherche Agronomique du Littoral (Togo)
CREA-CI-BG (ITA386)	Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA)-Centro di Ricerca Cerealicoltura e Colture Industriali - sede di Bergamo (Italy)
CREA-CI-LAB-CE (ITA403)	CREA-Centro di Ricerca Cerealicoltura e Colture Industriali - Laboratorio tabacco di Caserta (Italy)
CREA-OFA-ACI (ITA226)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura e Agrumicoltura, sede di Acireale (Italy)
CREA-OFA-FC (ITA380)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura e Agrumicoltura, sede di Forlì (Italy)
CREA-OFA-REN (ITA401)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura e Agrumicoltura, Sede di Rende (Italy)
CREA-OFA-RM (ITA378)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura Agrumicoltura - Sede di Roma (Italy)
CREA-VE-CON (ITA388)	CREA-Centro di Ricerca Viticoltura ed Enologia, sede di Conegliano (Italy)
CREA-ZA-LO (ITA394)	CREA-Centro di Ricerca Zootecnia e Acquacoltura, sede di Lodi (Italy)
CRFSA (ITA443)	Centro di Ricerca Sperimentazione e Formazione in Agricoltura "Basile Caramia" (Italy)
CRI (CZE122)	Crop Research Institute genebank (Czechia)
CRUS (MEX201)	Centro Regional Universitario Sur, Universidad Autónoma de Chapingo (Mexico)
DALRRD (ZAF062)	Genetic Resources Directorate, Department of Agriculture, Land Reform and Rural Development (South Africa)
DAV (USA028)	National Germplasm Repository USDA, ARS, University of California (United States)
DB NRRC (USA970)	Dale Bumpers National Rice Research Center, United States Department of Agriculture, Agricultural Research Services (United States)
DENAREF (ECU023)	Departamento Nacional de Recursos Fitogenéticos, Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
DNRS (MEX263)	Servicio Nacional de Inspección y Certificación de Semillas, Depositario Nacional de Referencia de Semillas (Mexico)
DRGRF (DEU630)	Deutsches Rosarium GRF im Westfalenpark Dortmund (Germany)
EEA Illpa-Puno (PER014)	Estación Experimental Agraria Illpa, Instituto Nacional de Innovación Agraria (Peru)
EBI (ETH085)	Ethiopian Biodiversity Institute (Ethiopia)
EEA INTA Cerro Azul (ARG1222)	Estación Experimental Agropecuaria Cerro Azul, Instituto Nacional de Tecnología Agropecuaria (Argentina)

(Cont.)

Acronyms	Names
EEA INTA Famaillá (ARG1217)	Estación Experimental Agropecuaria Famaillá, Instituto Nacional de Tecnología Agropecuaria (Argentina)
EECA (ECU308)	Estación Experimental Central de la Amazonia, Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
EE-Toralapa INIAF (BOL317)	Estación Experimental de Toralapa, Instituto Nacional de Innovación Agropecuaria y Forestal (Plurinational State of Bolivia)
EETP (ECU330)	Estación Experimental Tropical Pichilingue, Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
EET-SJM (CUB323)	Estación Experimental del Tabaco, Instituto de Investigaciones del Tabaco (Cuba)
EICB (CUB299)	Estación de Investigaciones de Cacao Baracoa, Instituto Nacional de Investigaciones Agroforestales (Cuba)
ETKI (EST019)	Estonian Crop Research Institute (Estonia)
Europa-Rosarium (DEU528)	Europa-Rosarium Sangerhausen (Germany)
FCCRI (TUR034)	Field Crop Central Research Institute (Türkiye)
FE RIO HATO SUR - CIARG (PAN076)	Finca Experimental Rio Hato Sur, Centro de Investigación Agropecuaria de Recursos Genéticos (Panama)
FOFIFA CRR-E (MDG017)	Station de Recherche Ivoloina-Toamasina, Centre National de la Recherche Appliquée au Développement Rural (Madagascar)
FOFIFA DRR (MDG036)	Département de Recherches Rizicoles, Centre National de la Recherche Appliquée au Développement Rural (Madagascar)
FOFIFA-Mahajanga (MDG018)	Centre de Recherche Régional du Nord Ouest, Centre National de la Recherche Appliquée au Développement Rural (Madagas-car)
FRUCTUS (CHE065)	FRUCTUS, Association Suisse pour la Sauvegarde du Patrimoine Fruitier (Switzerland)
FTGRÍ (AZE009)	Fruit and Tea Growing Research Institute (Azerbaijan)
GB-DOA (THA300)	Genebank, Department of Agriculture, Ministry of Agriculture and Cooperation (Thailand)
GB, MARDI (MYS220)	Genebank and Seed Centre, Malaysian Agricultural Research and Development Institute (Malaysia)
GEN (USA167)	Plant Genetic Resources Unit, Cornell University, New York State Agricultural Experiment Station, USDA, ARS (United States)
GeRRI (KEN212)	Genetic Resources Research Institute (Kenya)
GRBI (ZWE049)	Genetic Resources and Biotechnology Institute, Department of Agricultural Research for Development, Ministry of Agriculture, Mechanization and Irrigation Development (Zimbabwe)
GRI (AZE015)	Genetic Resources Institute (Azerbaijan)
GRU-JIC (GBR247)	Germplasm Resources Unit, John Innes Centre, Norwich Research Park (United Kingdom)
GSLY (USA176)	C.M. Rick Tomato Genetic Resources Center, Department of Vegetable Crops, University of California (United States)
HBROD (CZE027)	Potato Research Institute Havlickuv Brod Ltd. (Czechia)
HOLOVOU (CZE031)	Research and Breeding Institute of Pomology, Holovousy Ltd. (Czechia)
HRC, MARDI (MYS142)	Pusat Penyelidikan Hortikultur, Malaysian Agricultural Research and Development Institute (Malaysia)
HRIGRU (GBR006)	Warwick Genetic Resources Unit (United Kingdom)
IBBR (ITA436)	Istituto di Bioscienze e Biorisorse, Consiglio Nazionale delle Ricerche (Italy)
IBERS-GRU (GBR016)	Genetic Resources Unit, Institute of Biological, Environmental & Rural Sciences, Aberystwyth University (United Kingdom)
ICAMEX (MEX194)	Instituto de Investigación y Capacitación Agropecuaria, Acuícola y Forestal del Estado de México (Mexico)
ICB (UKR014)	Institute of Sugarbeet (Ukraine)
ICCI-TELAVUN (ISR003)	Lieberman Germplasm Bank, Institute for Cereal Crops Improvement, Tel Aviv University (Israel)
ICIA (ESP048)	Gobierno de Canarias. Consejería de Agricultura, Ganadería, Pesca y Medio Ambiente. Instituto Canario de Investigaciones Agrarias (Spain)
ICDP Pitesti (ROM009)	Research and Development Institute for Fruit Tree Growing Pitesti – Maracineni (Romania)

Acronyms	Names
ICIA (ESP048)	Gobierno de Canarias. Consejería de Agricultura, Ganadería, Pesca y Medio Ambiente. Instituto Canario de Investigaciones Agrarias (Spain)
ICRAF (KEN023)	World Agroforestry Center
IFAPACHU (ESP138)	Junta de Andalucía. Consejería de Agricultura y Pesca. Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica. Centro de Churriana (Spain)
IFAPACOR (ESP046)	Junta de Andalucía. Consejería de Agricultura y Pesca. Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica. Centro Alameda del Obispo (Spain)
IFG (BLR017)	Republican Unitary Enterprise 'Institute for Fruit Growing' (Belarus)
IGB (ISR002)	Israel Gene Bank for Agricultural Crops, Agricultural Research Organisation, Volcani Center (Israel)
IGPEB (UZB001)	Institute of Genetics and Plant Experimental Biology (Uzbekistan)
IHAR (POL003)	Plant Breeding and Acclimatization Institute (Poland)
IHK (UKR013)	Ivano-Frankivs'k Institute of Agroindustrial Production (Ukraine)
IIFT (CUB003)	Instituto de Investigaciones en Fruticultura Tropical (Cuba)
IK (UKR005)	Institute of Grain Growing (Ukraine)
IKA (UKR026)	Institute of Potato Production (Ukraine)
ILK (UKR015)	Institute of Bast Crops (Ukraine)
ILVO (BEL094)	Instituut voor Landbouw- en Visserijonderzoek (Institute for Agricultural and Fisheries Research) (Belgium)
IMIDA-FRU (ESP133)	Región de Murcia. Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario. Fruticultura (Spain)
IMIDRA (ESP080)	Comunidad de Madrid. Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio. Instituto Madrileño de Investigación y Desarrollo Rural (Spain)
INCA (CUB005)	Instituto Nacional de Ciencias Agrícolas (Cuba)
INCDA Fundulea (ROM002)	National Agricultural Research and Development Institute – Fundulea (Romania)
INCDCSZ Brasov (ROM018)	National Research and Development Institute for Potato and Sugar Beet Brasov (Romania)
InHort (POL101)	Research Institute of Horticulture (Poland)
INIA Carillanca (CHL150)	Instituto de Investigaciones Agropecuarias (Chile)
INIA Intihuasi (CHL028)	Banco Base de Semillas, Instituto de Investigaciones Agrope-cuarias Intihuasi (Chile)
INIA LE (URY003)	Instituto Nacional de Investigación Agropecuaria, La Estanzuela (Uruguay)
INIA-CRF (ESP004)	Centro Nacional de Recursos Fitogenéticos (Spain)
INIA-EEA.A (PER006)	Estación Experimental Agraria Santa Rita, Instituto Nacional de Innovación Agraria (Peru)
INIA-EEA.CAN (PER041)	Estación Experimental Agraria Canaán, Instituto Nacional de Innovación Agraria (Peru)
INIA-EEA.DONOSO (PER034)	Estación Experimental Agraria Donoso, Instituto Nacional de Innovación Agraria (Peru)
INIA-EEA.POV (PER017)	Estación Experimental Agraria El Porvenir, Instituto Nacional de Innovación Agraria (Peru)
INIA-EEA.SA. (PER029)	Estación Experimental Agraria Santa Ana, Instituto Nacional de Innovación Agraria (Peru)
INIA-EEA.SR. (PER016)	Estación Experimental Agraria San Roque, Instituto Nacional de Innovación Agraria (Peru)
INIAV-Elvas (PRT196)	Departamento de Olivicultura, Estação nacional de Melhoramento de Plantas (Portugal)
INICA (CUB041)	Instituto Nacional de Investigación de la Caña de Azúcar (Cuba)
INIVIT (CUB006)	Instituto Nacional de Investigaciones en Viandas Tropicales (Cuba)
INRA CRRAS (MAR088)	Centre Régional de la Recherche Agronomique de Settat (Morocco)
INRAe (FRA015)	Institut National de Recherche pour l'Agriculture, l'alimentation et l'environnement, Departement de biologie et amelioration des plantes (France)
INRAe-ANTILLE (FRA109)	Génétique et Amélioration des Plantes, Plant Biology and Breeding, INRAe Antilles-Guyane (France)

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Acronyms	Names
INRAe-AVIGNON (FRA011)	Unité de Génétique et Amélioration des Fruits et Légumes, Plant Biology and Breeding, INRAe Avignon (France)
INRAe-CLERMONT (FRA040)	Génétique Diversité et Ecophysiologie des Céréales, Plant Biology and Breeding, INRAe Clermont-Ferrand (France)
INRAe-COLMAR (FRA038)	UMR Santé de la vigne et qualité du vin, INRAe Centre Grand Est-Colmar (France)
INRAe-CORSE (FRA064)	Amélioration génétique et adaptation des plantes méditerranéennes et tropicales, INRAe-CIRAD (France)
INRAe-MONTPEL (FRA041)	Plant Biology and Breeding, INRAe Montpellier (France)
INRAe-RENNES (FRA010)	Institut de Génétique Environnement et Protection des Plantes, Plant Biology and Breeding, INRAe Ploudaniel (France)
INRAe-VASSAL (FRA139)	Centre de Ressources Biologiques de la Vigne de Vassal-Montpellier, Plant Biology and Breeding, INRAe Montpellier (France)
INRAN (NER001)	Institut national de la recherche agronomique du Niger (Niger)
IOB (UKR021)	Institute of Vegetable and Melon Growing (Ukraine)
IOK (UKR012)	Institute of Oil Crops (Ukraine)
IPAS (MNG030)	Institute of Plant and Agricultural Science (Mongolia)
IPB-NPGRL (PHL129)	Institute of Plant Breeding-National Plant Genetic Resources Laboratory (Philippines)
IPGR (BGR001)	Institute for Plant Genetic Resources 'K.Malkov' (Bulgaria)
IPK (DEU146)	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research (Germany)
IPK (DEU159)	External Branch North of the Department Genebank, IPK, Potato Collection in Gross-Luesewitz (Germany)
IPK (DEU271)	External Branch North of the Department Genebank, IPK, Oil Plants and Fodder Crops in Malchow (Germany)
IPRBON (POL002)	Potato Research Institute (Poland)
IR (UKR001)	Institute of Plant Production n.a. V.Y. Yurjev of UAAS (Ukraine)
IRD (FRA254)	Institut de Recherche pour le Développement (France)
IRTAMB (ESP014)	Generalitat de Catalunya. Institut de Recerca i Tecnologia Agroalimentàries. Centre Mas de Bover (Spain)
ISA (PRT018)	DRAT, DCEB - Instituto Superior de Agronomia (Portugal)
ISOPlexis (PRT102)	Banco de Germoplasma - Universidade da Madeira (Portugal)
ISRA-CNRA (SEN002)	Centre National de la Recherche Agronomique (Senegal)
IT-Altamirano (MEX178)	Instituto Tecnológico de Ciudad Altamirano (Mexico)
ITC (BEL084)	Bioversity International Musa Germplasm Transit Centre
IVIA (ESP025)	Generalidad Valenciana. Consellería de Agricultura, Pesca y Alimentación. Instituto Valenciano de Investigación Agraria (Spain)
IVM (UKR050)	Institute of Grape and Wine 'Maharach' (Ukraine)
IZ (UKR004)	Institute of Agriculture (Ukraine)
JB-IB-UNAM (MEX337)	Jardín Botánico del Instituto de Biología, Universidad Nacional Autónoma de México (Mexico)
JBQ (ECU212)	Jardín Botánico Ciudad de Quito (Ecuador)
JHI (GBR251)	The James Hutton Institute (United Kingdom)
JKI (DEU098)	Federal Research Centre for Cultivated Plants - Institute for Grapevine Breeding Geilweilerhof (Germany)
JKI (DEU451)	Federal Research Centre for Cultivated Plants - Institute of Fruit Breeding (Germany)
KLOST (AUT024)	Education and Research Centre for Viticulture and Pomology (Austria)
KPS (UKR046)	Crimean Pomological Station (Ukraine)
KST (UKR079)	Crimean Tobacco Experimental Station (Ukraine)
LFS (UKR029)	L'viv Experimental Station of Horticulture (Ukraine)

Acronyms	Names
LGGRB (MDA004)	Laboratory of Grapevine Genetic Resources and Breeding (Republic of Moldova)
LTS (BGD206)	Lal Teer Seed Limited (Bangladesh)
LTZ (DEU594)	Agricultural Technology Center Augustenberg – Forchheim (Germany)
LZSG (CHE109)	Kantonale Zentralstelle für Weinbau (Switzerland)
MAY (USA108)	Tropical Agricultural Research Station, Clonal Repository USDA/ARS (United States)
MGCSC; GSZE (USA174)	Maize Genetics Cooperation - Stock Center; Soybean/Maize Germplasm, Pathology & Genetics Research Unit, USDA/ARS/MWA/Urbana; Department of Crop Sciences, University of Illinois (United States)
MIA (USA047)	Subtropical Horticultural Research Unit, National Germplasm Repository - Miami, USDA (United States)
MIS (UKR034)	Mliyiv Institute of Horticulture (n.a. Symyrenko) (Ukraine)
MPGRC (MWI041)	Malawi Plant Genetic Resources Centre (Malawi)
MRC Bubia (PNG041)	Momase Regional Centre, Bubia (Papua New Guinea)
MRIZP (SRB001)	Maize Research Institute 'Zemun Polje' (Serbia)
MSB (MMR015)	Myanmar Seed Bank (Myanmar)
NACGRAB (NGA010)	National Centre for Genetic Resources and Biotechnology (Nigeria)
NAGRC (NPL069)	National Agriculture Genetic Resources Centre-Genebank (Nepal)
NAGU (USA151)	National Arboretum-Germplasm Unit, USDA/ARS (United States)
NARC-LSU (PHL152)	National Abaca Research Centre (Philippines)
NARI-HRC (PNG039)	National Agricultural Research Institute, Highlands Regional Centre – Aiyura (Papua New Guinea)
NARO (JPN183)	National Agriculture and Food Research Organization (Japan)
NBPGR (IND001)	National Bureau of Plant Genetic Resources (India)
NBS (UKR036)	Nikitskyi Botanical Gardens (Ukraine)
NC7 (USA020)	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS (United States)
NCGRP (USA995)	National Center for Genetic Resources Preservation (United States)
NE9 (USA003)	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, USDA-ARS, New York State Agricultural Experiment Station, Cornell University (United States)
NFC (GBR030)	National Fruit Collections, University of Reading (United Kingdom)
NGB (EGY087)	National Gene Bank (Egypt)
NODiK (HUN003)	Centre for Plant Diversity (Hungary)
NPGRC (BWA015)	National Plant Genetic Resources Centre (Botswana)
NPGRC (NAM006)	National Plant Genetic Resources Centre (Namibia)
NPGRC (TZA016)	National Plant Genetic Resources Centre (United Republic of Tanzania)
NPGRC (ZMB048)	National Plant Genetic Resources Centre (Zambia)
NR6 (USA004)	Potato Germplasm Introduction Station, USDA-ARS (United States)
NSGC (USA029)	National Small Grains Germplasm Research Facility, USDA-ARS (United States)
NSGC (USA029)	National Small Grains Germplasm Research Facility (United States)
NSL (USA476)	National Seed Laboratory (United States)
OPGC (USA956)	Ornamental Plant Germplasm Center, Ohio State University (United States)
OSS Roggwil (CHE090)	Verein Obstsortensammlung Roggwil (Switzerland)
PAN (POL001)	Botanical Garden of the Polish Academy of Sciences (Poland)

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Acronyms	Names
PERUG (ITA363)	Dipartimento di Chimica, Biologia e Biotecnologie, Universitá degli Studi Perugia (Italy)
PGRC (CAN004)	Plant Gene Resources of Canada, Saskatoon Research and Development Centre (Canada)
PGRC (LKA036)	Plant Genetic Resources Centre (Sri Lanka)
PGRC (UGA132)	Plant Genetic Resources Centre (Uganda)
PGRP (PAK001)	Plant Genetic Resources Program (Pakistan)
PGRRI (GHA091)	Plant Genetic Resources Research Institute (Ghana)
PhilRice (PHL158)	Philippine Rice Research Institute (Philippines)
PRC (VNM049)	Plant Resources Center (Viet Nam)
PRUHON (CZE079)	Research Institute of Landscaping and Ornamental Gardening (Czechia)
PSR (CHE063)	ProSpecieRara (Switzerland)
RBG (GBR004)	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Gardens, Kew, Wakehurst Place (United Kingdom)
RIV NCGRCD (USA129)	National Clonal Germplasm Repository for Citrus & Dates, USDA-ARS (United States)
RL (FRA364)	Roseraie Loubert (France)
RP (CHE066)	Rétropomme (Switzerland)
RPC-AF (BLR011)	Republican Unitary Enterprise "Research and Practical Centre of the National Academy of Sciences of Belarus for Arable Farming" (Belarus)
RPC-PFVG (BLR016)	Republican Unitary Enterprise "Research and Practical Center of the National Academy of Sciences of Belarus for Potato, Fruit and Vegetable Growing" (Belarus)
S9 (USA016)	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, University of Georgia, USDA-ARS (United States)
SAG (CHL171)	Servicio Agrícola y Ganadero (Chile)
SASA (GBR165)	Science and Advice for Scottish Agriculture, Scottish Government (United Kingdom)
SCDP Constanta (ROM035)	Research and Development Station for Fruit Tree Growing Constanta (Romania)
SCDP Vaslui (ROM080)	Agricultural Research and Development Grassland Station Vaslui (Romania)
SCRDC (VNM120)	Sugar Cane Research and Development Center
SIAEX (ESP010)	Junta de Extremadura. Dirección General de Ciencia y Tecnología. Centro de Investigación Agraria Finca La Orden - Valdesequera. (Spain)
SOY (USA033)	Soybean Germplasm Collection, USDA-ARS (United States)
SRC Laloki (PNG004)	Southern Regional Centre Laloki, National Agricultural Re-search Institute (Papua New Guinea)
SVKMSARIS (SVK002)	Plant Breeding Station (Slovakia)
SVKPIEST (SVK001)	Plant Production Research Center Piestany (Slovakia)
SVKVIGLAS (SVK003)	Breeding Research Station (Slovakia)
TOB (USA074)	US Nicotiana Germplasm Collection (United States)
UACH (CHL071)	Banco de Germoplasma de Papa, Universidad Austral de Chile (Chile)
UACh (MEX051)	Universidad Autónoma Chapingo (Mexico)
UDG-CUCBA (MEX131)	Universidad de Guadalajara, Centro Universitario de Ciencias Biológicas y Agropecuarias (Mexico)
UDS (UKR008)	Ustymivka Experimental Station of Plant Production (Ukraine)
UG (MEX257)	Universidad de Guanajuato (Mexico)
UNA (PER066)	Programa Cooperativo de Investigación en Maíz, Universida Na-cional Agraria La Molina (Peru)
UPM (MYS125)	Universiti Putra Malaysia

Acronyms	Names
USFQ (ECU098)	Laboratorio de Biotecnología Vegetal, Universidad San Francisco de Quito (Ecuador)
UzRICBSP (UZB036)	Uzbek Research Institute of Cotton Breeding and Seed Production (Uzbekistan)
UzRIPI (UZB006)	Uzbek Research Institute of Plant Industry (Uzbekistan)
VINATRI (VNM025)	Tea Research Institute (Viet Nam)
VIR (RUS001)	N.I. Vavilov All-Russian Research Institute of Plant Industry (Russian Federation)
W6 (USA022)	Western Regional Plant Introduction Station, USDA-ARS, Washington State University (United States)
WASI (VNM085)	The Western Highlands Agro-Forestry Science and Technical Institute (Viet Nam)

Plant genetic resources for food and agriculture are the essence of sustainable agrifood systems. They encompass the genetic diversity in both improved and farmers' varieties, as well as in crop wild relatives, wild food plants and breeding materials.

The *Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* presents a comprehensive assessment of the conservation and sustainable use of PGRFA, as well as the human and institutional capacities to support these efforts. Based on information from 128 countries and four regional and 13 international research centres and the contribution from over 1 600 experts, it presents an overview of progress since 2012, as well as current needs and challenges in the future management of plant genetic resources for food and agriculture. It provides a sound basis for recalibrating relevant polices and strategies, including the rolling Global Plan of Action for Plant Genetic Resources for Food and Agriculture.

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