GLOBAL CROP CONSERVATION AND USE METRICS

TROPICAL AND SUBTROPICAL FORAGES

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Global crop conservation and use metrics

TROPICAL AND SUBTROPICAL FORAGES

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International Treaty on Plant Genetic Resources for Food and Agriculture

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Description

This report provides an up-to-date overview of the global status of *ex situ* conservation of genetic resources of tropical and subtropical forages and their wild relatives, including key metrics on:

- the identity and composition of genebank collections;
- the Multilateral System (MLS) status of accessions in these collections;
- storage, regeneration, and safety duplication status;
- documentation, information systems, and research resources;
- germplasm distribution; and
- varietal registrations and releases.

The report also includes global statistics on crop production and trade, as well as information about crop networks and partnerships. It is meant to provide an update to some of the information presented in the Global Conservation Strategy for tropical and subtropical forages (Crop Trust, 2015), but is primarily based on publicly available datasets, rather than a new survey of genetic resource collections and expert consultations.

Introduction and background on tropical and subtropical forages

Major tropical and subtropical forage crops, primarily grasses and legumes, serve as a principal source of nutrition for ruminant livestock in developing countries, contributing to the supply of meat and milk, as well as products such as leather and wool (Fuglie *et al.*, 2021). These forages originated mainly from Africa and the Americas, as well as Asia and other regions (Crop Trust, 2015; USDA, 2025), with current production primarily concentrated in Latin America (Fuglie *et al.*, 2021). These crops have been developed through breeding programs over the past half century to provide higher-yielding varieties with tolerances to various environmental stresses. Cultivated forage crops in developing countries are estimated to cover at least 159 million hectares and produce products worth $63 billion per year (Fuglie *et al.*, 2021). The utility of forage legumes is underpinned by their ability to thrive in poor soils and to provide protein-rich fodder for livestock while also improving soil organic matter, water holding capacity, and nutrient cycling when used in rotation with cereals and other field crops (Crop Trust, 2015). Some of the crops, such as some members of the genus *Urochloa* P. Beauv. [syn. *Brachiaria* (Trin.) Griseb.] can suppress soil-nitrification and thus reduce agriculture-related greenhouse gas emissions (Subbarao *et al.*, 2009).

Table 1. Major *ex situ* collections of tropical and subtropical forage genetic resources. Top 20 institutions listed in descending order by total number of accessions. Number of accessions and storage condition information from Genesys and FAO WIEWS (2024), with supplementary information as noted. Multilateral System (MLS) status from Plant Treaty GLIS (2025) and from Genesys and FAO WIEWS (2024).

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
COL003	International Center for Tropical Agriculture/ Centro Internacional de Agricultura Tropical (CIAT)	13,700	14.2%	14.2%	Not listed*	15,926	13,700
JPN183	NARO Genebank	12,733	13.2%	27.4%	1,415	14	3
AUS167	Australian Pastures Genebank	12,119	12.6%	39.9%	240	12,477	12,088
IND001	National Bureau of Plant Genetic Resources (NBPGR)	9,499	9.8%	49.8%	Not listed	0	0
KEN212	Genetic Resources Research Institute	8,549	8.8%	58.6%	Not listed	1,058	703
ETH013	International Livestock Research Institute (ILRI)	7,107	7.4%	66.0%	Not listed*	7,345	7,080
USA016	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, University of Georgia, USDA-ARS	6,148	6.4%	72.3%	Not listed*	0	0
BRA003	Embrapa Recursos Genéticos e Biotecnologia	2,525	2.6%	74.9%	Not listed	0	0
NER001	Institut national de la recherche agronomique du Niger	2,501	2.6%	77.5%	Not listed	128	2,494
NZL001	Margot Forde Genebank, AgResearch Ltd	2,172	2.2%	79.8%	51	0	0
BRA034	Embrapa Cerrados	1,633	1.7%	81.5%	Not listed	0	0
GBR004	Millennium Seed Bank - Royal Botanic Gardens Kew	1,534	1.6%	83.1%	Not listed	0	213
ARE003	International Center for Biosaline Agriculture	1,373	1.4%	84.5%	Not listed	906	1,373
USA995	National Center for Genetic Resources Preservation	1,051	1.1%	85.6%	17	0	0
GBR016	Genetic Resources Unit, Institute of Biological, Environmental & Rural Sciences, Aberystwyth University	1,042	1.1%	86.6%	Not listed	0	39
CUB010	Estación Experimental de Pastos y Forrajes Indio Hatuey	975	1.0%	87.7%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
USA022	Western Regional Plant Introduction Station, USDA-ARS, Washington State University	957	1.0%	88.6%	Not listed*	0	0
BEL014	Botanic Garden Meise	739	0.8%	89.4%	Not listed	0	739
URY003	INIA La Estanzuela	526	0.5%	90.0%	Not listed	0	0
TUN029	Banque Nationale de Gènes de Tunisie	507	0.5%	90.5%	Not listed	0	0
	Other institutions (n = 155)	9,192	9.5%	100.0%	14	35,294	2,517

*But known to be maintaining forage seed collections in long-term conditions

Identity and composition of *ex situ* collections

For this analysis of tropical and subtropical forage germplasm collections, to identify a pragmatic number of forage crops to assess, we surveyed the genera with the most forage crop accessions in Genesys, removing accessions of forage crops clearly only pertinent to temperate environments. We then further edited this list based on inputs from the International Center for Tropical Agriculture (CIAT) and the International Livestock Research Institute (ILRI), which maintain the largest international tropical and subtropical forage collections in the CGIAR, as well as from the author of the 2015 Global Conservation Strategy for tropical and subtropical forages. This process yielded a prioritized list of forage taxa across 24 genera [*Aeschynomene, Alysicarpus, Andropogon, Cenchrus (*syn. *Pennisetum), Centrosema, Chloris, Chrysopogon, Clitoria, Cynodon, Desmanthus, Desmodium, Digitaria, Lablab, Leucaena, Lotus, Macroptilium, Megathrysus, Panicum, Paspalum, Sesbania, Setaria, Stylosanthes, Urochloa (*syn. *Brachiaria),* and *Vigna*]. To avoid imbalanced results due to several food crop taxa also being within these genera, we removed accessions of food crop taxa identified in the dataset, including under the names: *Cenchrus americanus* (L.) Morrone (pearl millet), *Digitaria exilis* (Kippist) Stapf (white fonio), *Digitaria iburua* Stapf (black fonio), *Lablab purpureus* (L.) Sweet (lablab), *Panicum miliaceum* L. and *Panicum miliaceum* subsp. *miliaceum* (proso millet), *Panicum sumatrense* Roth (little millet), *Paspalum scrobiculatum* L. (kodo millet), *Setaria italica* (L.) P. Beauv. (foxtail millet), *Vigna aconitifolia* (Jacq.) Maréchal (mat bean), *Vigna angularis* (Willd.) Ohwi & H. Ohashi (adzuki bean), *Vigna mungo* (L.) Hepper (black gram), *Vigna radiata* (L.) R. Wilczek and *Vigna radiata* var. *radiata* (mung bean), *Vigna subterranea* (L.) Verdc. (bambara groundnut), *Vigna umbellata* (Thunb.) Ohwi & H. Ohashi (ricebean), and *Vigna unguiculata* (L.) Walp., *Vigna unguiculata* group sesquipedalis, and *Vigna unguiculata* subsp. *unguiculata* (cowpea).

Latin America and the Caribbean are key regions of diversity for tropical and subtropical legume forages in *Stylosanthes, Leucaena, Desmodium,* and *Centrosema*, while many of the grasses, such as those in *Urochloa*, *Cenchrus*, and *Panicum,* originate from sub-Saharan Africa (Crop Trust, 2015; 2025). Major exceptions include the legume genus *Vigna*, which is mostly African in origin. For grasses, *Paspalum* has several species of importance from the Americas.

Based on the latest information in global genetic resource databases, germplasm collections of assessed tropical and subtropical forages and their wild relatives are present in at least 175 institutions worldwide, collectively maintaining 96,582 accessions (Table 1, Table 2; Supplementary Table 1). The institutions are distributed globally, including large collections in Africa, the Americas, Asia, Australia, and Europe. The International Center for Tropical Agriculture (CIAT) and the International Livestock Research Institute (ILRI), hold large international collections of the assessed tropical and subtropical forage genera, with the International Center for Biosaline Agriculture, International Centre for Agricultural Research in Dry Areas (ICARDA), and the World Agroforestry Centre also holding smaller collections (see Supplementary Table 1). The largest national collections are in Japan, Australia, India, Kenya, USA, Brazil, Niger, New Zealand, and the UK. The combination of these international and larger national collections maintain over 85% of documented accessions worldwide.

The International Board for Plant Genetic Resources (IBPGR)/International Plant Genetic Resources Institute (IPGRI) Register of Base Collections, which included collections that had formed (or had been proposed for) agreements with the international institutions based on long-term conservation of crop genepools on global or regional bases during the 1970s through 1990s (IBPGR/IPGRI, 1993; Thormann et al., 2019), listed, for forage crops in the assessed genera:

- CIAT and ILRI
- Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Tropical Crops & Pastures, Brisbane (Australia) – global collections of *Cenchrus, Centrosema, Desmanthus, Desmodium, Digitaria, Macroptilium, Stylosanthes*, and *Urochloa* (agreement dated 1986)
- National Institute of Agrobiological Science (NIAS) (Japan) – global collections of *Panicum* and *Chloris* (agreement dated 1985)
- Royal Botanic Gardens Kew, Seed Bank (UK) – global collections of *Cenchrus* and *Digitaria* (agreement dated 1985)

Based on the number of current accessions (Table 2, Supplementary Table 1), it appears that all of these recognized collections continue to maintain diverse forage germplasm, noting that names of some institutions have changed.

Data compilation for this report on tropical and subtropical forage genetic resources included all taxa in the 24 assessed genera, aside from

Table 2. Composition of *ex situ* collections of tropical and subtropical forages genetic resources. Main *ex situ* collections data from Genesys and FAO WIEWS (2024). Primary and secondary regions information from Khoury *et al.* (2023) and subsequent research for this summary. Botanic gardens data from BGCI PlantSearch (2024).

Metric	Number	Percentage
Total number of accessions in genebank collections	96,582	
Number of institutions holding genebank collections	175	
Number of distinct taxonomic names in genebank collections	956	
Number of accessions of crop wild relatives (CWR) in genebank collections	45,088	46.7%
Number of accessions of weedy materials in genebank collections	135	0.14%
Number of accessions of landraces in genebank collections	5,832	6.0%
Number of accessions of breeding materials in genebank collections	10,861	11.3%
Number of accessions of improved varieties in genebank collections	1,955	2.0%
Number of accessions of other materials in genebank collections	29	0.03%
Number of accessions not marked with an improvement type in genebank collections	32,682	33.8%
Number of countries where germplasm has been collected for genebank collections	192	
Number of taxa in botanic garden collections	599	
Number of botanic gardens holding collections of crop or its wild relatives	417	

excluded food crops. From these genera, a total of 956 taxa are present in germplasm collections (Supplementary Table 2).

Wild germplasm makes up the largest proportion of collections (46.7%), followed by breeding materials (11.3%), landraces (6.0%), and improved varieties (2.0%) (Table 2); these percentages are estimates based on available data, noting that 33.8% of accessions do not have biological status data. Tropical and subtropical forage germplasm has been collected from at least 192 countries. Information on botanic garden collections from BGCI PlantSearch indicate that 417 botanic gardens collectively conserve 599 tropical and subtropical forage taxa; comparing these to genebank collections, 104 are only present in botanic gardens.

Aside from tropical and subtropical forage taxa in the assessed genera entirely missing from, or with very small representation in, germplasm collections, the genetic resources databases do not offer insights on diversity gaps. Missing information on genetic resource collections leads to uncertainty regarding potential germplasm gaps; for example 4.5% of forage landrace accessions and 19.4% of wild relative accessions in the global genetic resources databases do not contain information even of the country where the accession was collected.

Multilateral System status of accessions in *ex situ* collections

Approximately 26 taxa in 12 forage grass genera and 52 taxa in 15 forage legume genera, as well as two genera that are neither grasses nor legumes, are listed in Annex I of the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) and are thus included in its Multilateral System of Access and Benefit Sharing (MLS) (FAO, 2009). The 2015 Strategy pointed out that the great majority of tropical and subtropical forages are not listed in Annex 1 (Crop Trust, 2015). In terms of the 24 genera accessed for this report, only two (*Andropogon* and *Lotus*) are currently listed as forages covered in Annex 1. Two other genera [*Pennisetum* (now *Cenchrus*), and *Vigna*] are included in the food crop section of Annex 1. For this analysis we counted all taxa in *Andropogon* and *Lotus* as included in Annex 1, but did not count any *Cenchrus* or *Vigna* taxa, as this report strictly considers forage germplasm.

Of the 96,582 accessions of assessed tropical and subtropical forage taxa conserved globally, approximately 23% are held in international institutions (i.e., CIAT, ILRI, International Center for Biosaline Agriculture, ICARDA, and the World Agroforestry Centre, and are included in the MLS under Article 15 of the Plant Treaty, with the remainder maintained in national and other collections (Table 3).

As of 2025, 75,779 accessions are formally included in the MLS according to the Plant Treaty's GLIS database, and 89,471 accessions have been assigned Digital Object Identifiers (DOIs). Per the relevant fields in the global genetic resources databases, 40,949 accessions (42.4% of world total) are listed as included in the MLS; this is likely an underestimate, noting that 26.3% of accessions do not have MLS status data.

Table 3. Representation of tropical and subtropical forage accessions in international and national institutions, number of accessions with DOIs, and representation of accessions in the Multilateral System of Access and Benefit Sharing of the International Treaty on Plant Genetic Resources for Food and Agriculture. Main *ex situ* collections data from Genesys and FAO WIEWS (2024). DOI and MLS data from Plant Treaty GLIS (2025).

Metric	Number	Percentage
Number of accessions in genebank collections in international institutions	22,721	23.5%
Number of accessions in genebank collections in national or other institutions	73,861	76.5%
Number of accessions in genebank collections in Annex I	30,079	31.1%
Number of accessions with DOI (Plant Treaty GLIS 2025)	89,471	
Number of accessions included in the Multilateral System (MLS) (Plant Treaty GLIS 2025)	75,779	
Number of accessions included in the Multilateral System (MLS) (genebank collections databases)	40,949	42.4%
Number of accessions included in the Multilateral System (MLS) that are in international collections (genebank collections databases)	22,618	23.4%
Number of accessions not included in the Multilateral System (MLS) (genebank collections databases)	30,207	31.3%
Number of accessions without information regarding inclusion in the Multilateral System (MLS) (genebank collections databases)	25,426	26.3%

Storage conditions, regeneration status, and safety duplication

Most of the assessed tropical and subtropical forage taxa produce orthodox seed, and over 70% of accessions conserved worldwide are thus conserved as seed, with at least 47.1% of these accessions listed as conserved under long-term cold-storage conditions (Table 4). Information on storage in general is missing for 28.3% of all accessions, and on seed storage type (i.e., long, medium, or short term) information is missing for 30.8% of seed accessions.

Current regeneration status and needs cannot be directly derived from the global germplasm databases. The 2015 Strategy did not provide specific information on regeneration status, noting that a compiled list of forage germplasm collections, and their status, was first needed (Crop Trust, 2015). FAO WIEWS reporting for the *Third State of the World's Plant Genetic Resources for Food and Agriculture* (FAO, 2025b) for the years 2014 to 2019, documented 1,348 tropical and subtropical forage accessions (of the genera assessed here) regenerated during this time by reporting institutions, with 6,344 accessions identified as needing regeneration and 5,865 of these lacking funds to conduct the regeneration.

The 2015 Strategy noted that safety backup collections are held by a range of institutes, some in the same country (including for Australia and USA), and others internationally. Specifically, the Strategy mentioned that the Australian collection had been sent to ILRI and/or CIAT; a significant proportion of the forage accessions at CIAT were also in two or more other genebanks, including Australia, Brazil, USA or ILRI, as a result of joint collecting missions; and that some of the South African grass and legume collections were held in the Australian collection (Crop Trust, 2015). In summary, the Strategy

assessed that thousands of forage accessions are in several active collections, serving an informal (as it was not comprehensively documented) safety back up role. This said, the Strategy remarked that many of the survey respondents reported that less than 10% of their collections was backed-up in other institutes.

Analysis of the location of safety duplication sites of assessed tropical and subtropical forage genera accessions, as listed in Genesys, indicates that almost half (48.5%) of accessions listed are safety duplicated in an active collection (i.e., apart from potentially being duplicated at the Svalbard Global Seed Vault [SGSV]) outside of the country of the main collection (Table 4). Actual extent of safety duplication of forage accessions worldwide, when also considering safety duplication within the same country, may be higher than this estimate, given that a number of national genebanks (such as the USA and Russian Federation) typically provide safety backup of their collections in a different location within the country. Information from the SGSV database from 2024 indicated that approximately 63.4% of total accessions worldwide were duplicated in Svalbard.

Table 4. Storage conditions of tropical and subtropical forage *ex situ* collections, regeneration status, and safety duplication status. Main *ex situ* collections data from Genesys and FAO WIEWS (2024). Regeneration status information from FAO WIEWS (2024); data from 2014 to 2019. Safety duplication out of the country data based only on Genesys (2024) data. Svalbard Global Seed Vault data from SGSV portal (2024).

Metric	Number	Percentage
Number of accessions held in seed storage in genebank collections	67,768	70.2%
Number of accessions held in short-term seed storage in genebank collections	0	0%
Number of accessions held in medium-term seed storage in genebank collections	15,026	22.2%
Number of accessions held in long-term seed storage in genebank collections	31,894	47.1%
Number of accessions held in seed storage of undefined type in genebank collections	20,848	30.8%
Number of accessions held in field storage in genebank collections	1,910	2.0%
Number of accessions held in in-vitro storage in genebank collections	0	0%
Number of accessions held in cryo storage in genebank collections	101	0.10%
Number of accessions held as DNA in genebank collections	131	0.14%
Number of accessions held in other storage in genebank collections	0	0%
Number of accessions not marked with a storage type in genebank collections	27,283	28.3%
Number of accessions in genebank collections regenerated 2014–2019	1,348	13.2%
Number of accessions in genebank collections in need of regeneration 2014–2019	6,344	62.1%
Number of accessions in genebank collections in need of regeneration without budget for regeneration 2014–2019	5,865	57.4%
Number of accessions safety duplicated out of the country in genebank collections	16,517	48.5%
Number of accessions in genebank collections safety duplicated in Svalbard	61,229	63.4%

Documentation, information systems, and research resources

Descriptor lists relevant to forage grasses include an original list published in 1985 (IPBGR, 1985) and key descriptors for forage grasses published in 2023 (Muchugi *et al.*, 2023). Likewise, descriptor lists relevant to forage legumes include an original list published in 1984 (IBPGR, 1984) and key descriptors for forage legumes published in 2023 (Hanson *et al.*, 2023).

A global knowledge base for tropical and subtropical forages, compiling knowledge produced since 1950 and providing recommendations, selection tools, and fact sheets on forages, was introduced at the International Grassland Congress in 2005 and updated a decade later (Alliance of Bioversity International and CIAT, 2025).

The estimated completeness of passport information for forage accessions listed in Genesys was 7.3 on a scale of 0 (no data) to 10 (complete data), which indicates that much data is available. At least 31 tropical and subtropical forage characterization and evaluation datasets are available via Genesys, covering a total of 31,432 accessions. Four metrics of the current degree of digital sequence information (DSI) for the assessed forage crops (from the National Center for Biotechnology Information USA database), two metrics of published literature on the crops (Google Scholar and PubMed Central), and one metric of the degree of research resources such as herbarium specimens (from the Global Biodiversity Information Facility - GBIF), are listed in Table 5.

The 2015 Strategy identified the following major needs regarding documentation and information systems at that time:

- Several collections had existing characterization data that were not easily available

Table 5. Documentation, information systems, and research resources for tropical and subtropical forages. Passport data completeness index (PDCI) from Genesys (2024), based on the methods outlined in van Hintum *et al*. (2011). Global Biodiversity Information Facility data from GBIF (2025). All other metrics data from Khoury *et al*. (2023).

Metric	Number
Passport data completeness index (range 0-10) as a median value across accessions in genebank collections	7.3
Number of genes as recorded in NCBI's Entrez database as of 2022	44,573
Number of genomes as recorded in NCBI's Entrez database as of 2022	12
Number of nucleotides as recorded in NCBI's Entrez database as of 2022	954,918
Number of proteins as recorded in NCBI's Entrez database as of 2022	347,398
Number of publications listed in Google Scholar with taxon name in title published between 2009 and 2019	12,045
Number of publications listed in PubMed Central with taxon name in text as of 2022	47,377
Number of research materials as recorded in GBIF (2025)	14,427,670

elsewhere and were not connected to their genetic resources databases, primarily because the databases could not easily accommodate these data. A priority was to publish these datasets.

- Many of the global priorities and needs for forage genetic resources were difficult to identify due to a lack of a truly comprehensive list of the world's collections and information on the status of the accessions within them. The Strategy prioritized building such a list, and moving towards a uniform information system which could facilitate the sharing of data across forage collections and therefore enable clarification of regeneration, safety duplication, and other needs (Crop Trust, 2015).

Information management for crop genetic resources has evolved substantially since the 2015 Strategy. GRIN Global, an adaptable and freely available genebank data management system, has been developed and deployed (Crop Trust, USDA, and Bioversity International, 2025). The current Genesys and FAO WIEWS databases offer some taxonomic, institutional, and passport data, and Genesys has developed the capacity to hold characterization data, which has been implemented for 31 forage datasets to date. This said, it is apparent that for tropical and subtropical forages, a dedicated online information system including complete accession-level characterization and evaluation data remains a gap.

Germplasm distributions and varietal registrations and releases

Germplasm distribution and varietal development statistics for tropical and subtropical forages are listed in Table 6. Germplasm distribution data from FAO WIEWS and the Plant Treaty Data Store reflect different reporting scopes: FAO WIEWS primarily reports distributions from national genebanks, while the Plant Treaty Data Store includes all transfers made under the SMTA, encompassing distributions made by genebanks as well as by breeding programs and other organizational types (Khoury *et al.*, 2025). From these data, as well as information on varietal registrations and releases, it is evident that tropical and subtropical forages are very actively distributed and that there are productive breeding programs.

The 2015 Strategy mentioned that tropical and subtropical forages were not as commonly developed through breeding pipelines as were major food crops, and that, instead, many accessions were directly multiplied and used in production systems (Crop Trust, 2015). The high numbers of distributions relative to varietal registrations and releases, compared to major food crops, may be a reflection of this more direct pipeline from genebanks.

Table 6. Tropical and subtropical forages germplasm distributions and varietal registrations and releases. FAO WIEWS distributions data is annual average over years 2014 to 2019. Plant Treaty Data Store distributions data is annual average over years 2015 to 2021. Evenness metric quantifies evenness of germplasm distributions across world regions, where 0 equals highly uneven and 1 equals completely even. International Union for the Protection of New Varieties of Plants (UPOV) PLUTO data is annual average over years 2014 to 2018. FAO WIEWS varietal releases data is annual average over years 2015 to 2019. All metrics data from Khoury *et al*. (2023), with Plant Treaty Data Store additions for more recent years (2019 to 2021).

Metric	Number
Average annual number of accessions distributed worldwide as recorded in FAO WIEWS	3,378.2
Average annual number of samples distributed worldwide as recorded in FAO WIEWS	5,004.0
Average annual number of samples distributed worldwide as recorded in the Plant Treaty Data Store	11,238.6
Number of countries receiving germplasm as recorded in the Plant Treaty Data Store	41.3
Evenness of distributions across world regions as recorded in the Plant Treaty Data Store	0.7
Average annual number of varietal registrations worldwide as recorded in UPOV's PLUTO	23.2
Average annual number of varietal releases worldwide as recorded in FAO WIEWS	67.5

Networks and partnerships

- CIAT, ILRI, and several other international institutions continue to play important roles in tropical and subtropical forage germplasm conservation and varietal development, maintaining active partnerships with national agricultural research organizations and several academic and industry institutions.
- The 2015 Strategy did not remark on existing networks focused on tropical and subtropical forage genetic resources, but did, as a central priority, identify the need for the development of such a network (Crop Trust, 2015).
- Information on networks active in tropical and subtropical forage conservation or use is not readily available online.

Conclusions

Tropical and subtropical forages continue to be an extremely important set of plant species in these regions of the world, and it is possible that they will grow in importance in future food systems as demand for animal products continues to rise, as does demand for efficient and ecologically sensitive production. Genetic resources of these forages are bolstered by the activities taking place in CIAT, ILRI, and other international institutions, as well as in several national and other collections. Available data indicates that there has been significant progress made in safety duplication and in information system development over the past decade, and there are considerable amounts of associated research resources and significant activity in germplasm distributions and varietal development. This said, further and increased efforts are needed to comprehensively include all unique forage germplasm collections in long-term storage, place these collections under the MLS of the Plant Treaty as pertinent, make the information accompanying accessions more complete and/or more accessible in online databases, and address regeneration and safety duplication backlogs.

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Methods and materials

Primary data sources for the metrics reported in this summary include: Genesys; World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture of the Food and Agriculture Organization of the United Nations (FAO WIEWS); Botanic Gardens Conservation International PlantSearch database (BGCI PlantSearch); Global Information System of the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty GLIS); Data Store of the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty Data Store); Svalbard Global Seed Vault portal (SGSV portal); International Union for the Protection of New Varieties of Plants (UPOV) PLUTO database; FAOSTAT; National Center for Biotechnology Information's Entrez database (NCBI Entrez); Google Scholar; PubMed Central; Wikipedia; and the Global Biodiversity Information Facility (GBIF). Some of these data were acquired from literature/databases including Khoury *et al*. (2023) and Khoury *et al*. (2025). Data processing, metric calculation, and table generation were conducted in R, with code available on this GitHub repository. Extended methods are available here.

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Supplementary information

Supplementary Table 1: Full list of *ex situ* collections of tropical and subtropical forages genetic resources, in descending order by total number of accessions. Number of accessions and storage condition information from Genesys and FAO WIEWS (2024), with supplementary information as noted. Multilateral System (MLS) status from Plant Treaty GLIS (2025) and from Genesys and FAO WIEWS (2024).

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
COL003	Centro Internacional de Agricultura Tropical	13,700	14.2%	14.2%	Not listed*	15,926	13,700
JPN183	NARO Genebank	12,733	13.2%	27.4%	501	14	3
AUS167	Australian Pastures Genebank	12,119	12.6%	39.9%	12,102	12,477	12,088
IND001	National Bureau of Plant Genetic Resources	9,499	9.8%	49.8%	1,709	0	0
KEN212	Genetic Resources Research Institute	8,549	8.8%	58.6%	5,935	1,058	703
ETH013	International Livestock Research Institute	7,107	7.4%	66.0%	Not listed*	7,345	7,080
USA016	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, University of Georgia, USDA-ARS	6,148	6.4%	72.3%	4,783	0	0
BRA003	Embrapa Recursos Genéticos e Biotecnologia	2,525	2.6%	74.9%	1,706	0	0
NER001	Institut national de la recherche agronomique du Niger	2,501	2.6%	77.5%	Not listed	128	2,494
NZL001	Margot Forde Genebank, AgResearch Ltd	2,172	2.2%	79.8%	Not listed	0	0
BRA034	Embrapa Cerrados	1,633	1.7%	81.5%	Not listed	0	0
GBR004	Millennium Seed Bank - Royal Botanic Gardens Kew	1,534	1.6%	83.1%	Not listed	0	213
ARE003	International Center for Biosaline Agriculture	1,373	1.4%	84.5%	Not listed	906	1,373
USA995	National Center for Genetic Resources Preservation	1,051	1.1%	85.6%	64	0	0
GBR016	Genetic Resources Unit, Institute of Biological, Environmental & Rural Sciences, Aberystwyth University	1,042	1.1%	86.6%	Not listed	0	39
CUB010	Estación Experimental de Pastos y Forrajes Indio Hatuey	975	1.0%	87.7%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
USA022	Western Regional Plant Introduction Station, USDA-ARS, Washington State University	957	1.0%	88.6%	787	0	0
BEL014	Botanic Garden Meise	739	0.8%	89.4%	722	0	739
URY003	INIA La Estanzuela	526	0.5%	90.0%	442	0	0
TUN029	Banque Nationale de Gènes de Tunisie	507	0.5%	90.5%	468	0	0
BRA019	Embrapa Pecuária Sudeste	498	0.5%	91.0%	Not listed	0	0
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	497	0.5%	91.5%	214	0	497
RUS001	N.I. Vavilov All-Russian Research Institute of Plant Industry	492	0.5%	92.0%	492	0	0
BRA035	Embrapa Tabuleiros Costeiros	446	0.5%	92.5%	Not listed	0	0
BRA010	Embrapa Gado de Corte	437	0.4%	92.9%	Not listed	0	0
MEX208	INIFAP, Centro Nacional de Recursos Genéticos (CNRG)	402	0.4%	93.4%	394	0	0
BGR001	Institute for Plant Genetic Resources 'K.Malkov'	325	0.3%	93.7%	21	0	0
ETH085	Ethiopian Biodiversity Institute	313	0.3%	94.0%	24	0	151
POL003	Plant Breeding and Acclimatization Institute	312	0.3%	94.3%	210	0	165
HUN003	Centre for Plant Diversity	298	0.3%	94.6%	35	0	47
BRA144	Embrapa Pecuária Sul	297	0.3%	95.0%	Not listed	0	0
CUB126	Estación Central de Pastos y Forrajes de Sancti Spiritus	289	0.3%	95.3%	Not listed	0	0
LBN002	International Centre for Agricultural Research in Dry Areas	259	0.3%	95.5%	Not listed*	214	224
GHA091	Plant Genetic Resources Research Institute	218	0.2%	95.7%	Not listed	539	211
ITA363	Dipartimento di Chimica, Biologia e Biotecnologie, Universitá degli Studi Perugia	206	0.2%	96.0%	193	0	0
KEN023	World Agroforestry Centre (Headquarters)	189	0.2%	96.2%	Not listed	1,271	189
BRA139	Embrapa Gado de Leite	165	0.2%	96.3%	Not listed	0	0
TZA016	National Plant Genetic Resources Centre	165	0.2%	96.5%	111	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
USA971	Desert Legume Program	155	0.2%	96.7%	Not listed	0	0
UGA132	Plant Genetic Resource Centre	151	0.2%	96.8%	12	0	132
BEN097	Unité de Génétique, Biotechnologie et Science des Semences	149	0.1%	97.0%	Not listed	0	0
DEU146	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research	142	0.1%	97.1%	109	168	74
BRA017	Embrapa Semi-Árido	140	0.1%	97.3%	Not listed	0	0
SEN002	Centre National de la Recherche Agronomique	112	0.1%	97.4%	Not listed	0	112
CZE122	Gene bank	110	0.1%	97.5%	102	11	110
MEX006	UACh, Banco Nacional de Germoplasma Vegetal (BANGEV)	104	0.1%	97.6%	24	0	0
SDN002	Agricultural Plant Genetic Resources Conservation and Research Centre	103	0.1%	97.7%	50	0	31
CUB251	Instituto de Investigaciones Agropecuarias Jorge Dimitrov	98	0.1%	97.8%	Not listed	0	0
UKR008	Ustymivka Experimental Station of Plant Production	86	0.1%	97.9%	15	0	0
SVK001	National Agricultural and Food Centre (NPPC), Research Institute of Plant Production (RIPP)	77	0.1%	98.0%	Not listed	0	75
ZMB048	National Plant Genetic Resources Centre	77	0.1%	98.1%	73	49	59
ISR002	Israel Gene Bank for Agricultural Crops, Agricultural Research Organisation, Volcani Center	70	0.1%	98.1%	18	0	0
MAR088	Centre Régional de la Recherche Agronomique de Settat	67	0.1%	98.2%	Not listed	0	0
PAK001	Plant Genetic Resources Program	64	0.1%	98.3%	41	0	49
UKR020	Institute of Forages	63	0.1%	98.3%	43	0	0
BLR011	Republican Unitary Enterprise 'Research and Practical Centre of the National Academy of Sciences of Belarus for Arable Farming'	55	0.1%	98.4%	14	0	0
CUB287	Instituto de Ciencia Animal	55	0.1%	98.4%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
UKR084	Before-Carpathian Branch	55	0.1%	98.5%	2	0	0
JOR105	National Agricultural Research Center	52	0.0%	98.6%	Not listed	42	41
ECU023	Departamento Nacional de Recursos Fitogenéticos	50	0.0%	98.6%	7	0	2
NGA010	National Centre for Genetic Resources and Biotechnology	43	0.0%	98.6%	Not listed	1,094	0
ERI003	National Agricultural Research Institute	42	0.0%	98.7%	42	0	0
MWI041	Malawi Plant Genetic Resources Centre	42	0.0%	98.7%	42	3	31
ZAF058	Grassland Research Centre, Department of Agricultural Development	42	0.0%	98.8%	21	0	0
SVN019	Crops and Seed Production Department, Agricultural Institute of Slovenia	41	0.0%	98.8%	Not listed	0	1
ZMB030	SADC Plant Genetic Resources Centre	41	0.0%	98.9%	39	0	0
DEU502	Botanical Garden of the University of Osnabrück	39	0.0%	98.9%	Not listed	0	23
IND002	International Crop Research Institute for the Semi-Arid Tropics	36	0.0%	98.9%	30	29,544	36
ARG1350	Banco Activo de Germoplasma de La Consulta	34	0.0%	99.0%	Not listed	0	0
MEX020	INIFAP, Campo Experimental Rosario Izapa (CERI)	34	0.0%	99.0%	Not listed	0	0
PRT102	Banco de Germoplasma - Universidade da Madeira	31	0.0%	99.0%	30	0	31
BRA192	Embrapa Pantanal	29	0.0%	99.1%	Not listed	0	0
MEX231	INIFAP, Campo Experimental Tecomán (CETECO)	27	0.0%	99.1%	Not listed	0	0
CYP004	National (CYPARI) Genebank, Agricultural Research Institute, Ministry of Agriculture, Rural Development and Environment	25	0.0%	99.1%	15	0	0
EGY087	National Gene Bank	24	0.0%	99.2%	Not listed	0	0
AZE015	Genetic Resources Institute	23	0.0%	99.2%	Not listed	0	7

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
ITA394	CREA-Centro di Ricerca Zootecnia e Acquacoltura - Sede di Lodi	23	0.0%	99.2%	Not listed	12	12
BGD189	Bangladesh Livestock Research Institute	22	0.0%	99.2%	Not listed	0	0
ESP010	Junta de Extremadura. Dirección General de Ciencia y Tecnología. Centro de Investigación Agraria Finca La Orden - Valdesequera.	22	0.0%	99.2%	12	0	0
QAT004	Biotechnology Center, Ministry of Environment	22	0.0%	99.3%	21	22	22
ARM005	Institute of Botany	21	0.0%	99.3%	19	0	20
COL017	Corporación Colombiana de Investigación Agropecuaria, AGROSAVIA	21	0.0%	99.3%	Not listed	0	0
GRC005	Greek Genebank, Institute of Plant Breeding and Genetic Resources	21	0.0%	99.3%	Not listed	0	0
UKR001	Institute of Plant Production n.a. V.Y. Yurjev of UAAS	21	0.0%	99.4%	11	0	0
ZAF062	RSA National Plant Genetic Resources Centre	21	0.0%	99.4%	17	0	0
PHL129	Institute of Plant Breeding-National Plant Genetic Resources Laboratory	20	0.0%	99.4%	Not listed	0	0
TTO010	Central Experiment Station, Research Division, Ministry of Agriculture, Land and Fisheries	20	0.0%	99.4%	Not listed	0	0
ARG1415	Instituto de Fisiología y Recursos Genéticos Vegetales- CIAP (Centro de Investigaciones Agropecuarias) - INTA (Instituto Nacional de Tecnología Agropecuaria)	19	0.0%	99.4%	Not listed	0	0
ARG1351	Banco Activo de Germoplasma de Anguil	18	0.0%	99.5%	Not listed	0	0
CZE082	OSEVA PRO Ltd. Grassland Research Station	17	0.0%	99.5%	Not listed	0	17
ARM059	Agrobiotechnology Scientific Center	16	0.0%	99.5%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
BRA020	Embrapa Clima Temperado	16	0.0%	99.5%	Not listed	0	0
ECU308	Estación Experimental Central de la Amazonia	16	0.0%	99.5%	Not listed	0	6
ESP004	Centro Nacional de Recursos Fitogenéticos	16	0.0%	99.5%	9	0	6
AUT060	HBLFA Raumberg-Gumpenstein	15	0.0%	99.6%	15	0	13
LKA036	Plant Genetic Resources Centre	15	0.0%	99.6%	Not listed	0	0
THA300	Genebank	15	0.0%	99.6%	5	0	0
AUS165	Australian Grains Genebank, Agriculture Victoria	14	0.0%	99.6%	9	1,038	12
LBY006	National Bank for Plant Genetic Resources	14	0.0%	99.6%	Not listed	0	0
DEU022	Botanical Garden Berlin-Dahlem	13	0.0%	99.6%	Not listed	0	10
ROM007	Suceava Genebank	13	0.0%	99.6%	Not listed	3	4
BGD003	Bangladesh Agricultural Research Institute	12	0.0%	99.7%	12	0	5
BIH039	Institute of Genetic Resources, University of Banja Luka	12	0.0%	99.7%	3	0	0
CRI001	Centro Agronómico Tropical de Investigación y Enseñanza	12	0.0%	99.7%	12	40	12
DEU626	Pädagogische Hochschule Karlsruhe	12	0.0%	99.7%	Not listed	0	11
ESP117	Gobierno de Canarias. Consejería de Agricultura, Ganadería, Pesca y Medio Ambiente. Instituto Canario de Investigaciones Agrarias. Jardín de Aclimatación de La Orotava	12	0.0%	99.7%	Not listed	0	0
LBN020	Lebanese Agricultural Research Institute	12	0.0%	99.7%	6	3	5
MLI002	Institut d'Economie Rurale	11	0.0%	99.7%	11	891	11
CHL171	Banco de Semillas SAG Magallanes	10	0.0%	99.7%	10	0	0
GRC102	Hellenic Mediterranean University	10	0.0%	99.7%	Not listed	0	0
MMR015	Myanmar SeedBank	10	0.0%	99.8%	Not listed	0	0
BWA015	National Plant Genetic Resources Centre	9	0.0%	99.8%	9	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
MEX201	UACh, Centro Regional Universitario Sur (CRUS)	9	0.0%	99.8%	Not listed	0	0
SWZ015	National Plant Genetic Resources Centre	9	0.0%	99.8%	9	0	0
UKR014	Institute of Sugarbeet	9	0.0%	99.8%	Not listed	0	0
VNM072	National Institute for Soils and Fertilizers	9	0.0%	99.8%	Not listed	0	0
BLR014	State research institution 'Institute of Experimental Botany of the National Academy of Sciences of Belarus'	8	0.0%	99.8%	7	0	0
DEU515	Botanischer Versuchs- und Lehrgarten der Universitaet Regensburg	8	0.0%	99.8%	Not listed	0	6
NPL069	National Agriculture Genetic Resources Centre-Genebank	8	0.0%	99.8%	1	0	0
SEN075	Unité de Recherche en Culture In-vitro	8	0.0%	99.8%	Not listed	0	8
SWE054	Nordic Genetic Resource Center	8	0.0%	99.8%	8	7	6
ESP003	Comunidad de Madrid. Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingeniería Agronómica, Alimentaria y de Biosistemas . Banco de Germoplasma César Gómez Campo	7	0.0%	99.9%	6	0	0
HRV041	Faculty of Agriculture, University of Zagreb	7	0.0%	99.9%	2	0	2
MEX014	INIFAP, Campo Experimental Iguala (CEIGUA)	7	0.0%	99.9%	Not listed	0	0
PRT001	Banco Português de Germoplasma Vegetal	7	0.0%	99.9%	7	0	7
NAM006	National Plant Genetic Resources Centre	6	0.0%	99.9%	1	0	0
TJK027	National Center for Genetic Resources	6	0.0%	99.9%	4	0	6
BGD014	Bangladesh Forest Research Institute (BFRI)	5	0.0%	99.9%	Not listed	0	0
MEX194	Instituto de Investigación y Capacitación Agropecuaria, Acuícola y Forestal del Estado de México (ICAMEX)	5	0.0%	99.9%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	5	0.0%	99.9%	3	0	0
BLR026	The Polessye Institute of Plant Growing	4	0.0%	99.9%	Not listed	0	0
CRI085	CATIE - Banco de Germoplasma (Colecciones Semillas Ortodoxas)	4	0.0%	99.9%	3	0	4
CRI141	Universidad Técnica Nacional - Sede Atenas	4	0.0%	99.9%	1	0	0
GUY021	National Agricultural Research and Extension Institute	4	0.0%	99.9%	Not listed	0	0
MDG038	Fiompiana Fambolena Malagasy Norvéziana	4	0.0%	99.9%	Not listed	0	0
PHL024	Bureau of Plant Industry-Davao National Crop Research and Development Center	4	0.0%	99.9%	Not listed	0	0
ROM003	Research and Development Institute for Meadows Brasov	4	0.0%	99.9%	Not listed	0	0
ROM068	Research and Development Station for Vegetables Buzau	4	0.0%	99.9%	Not listed	0	0
ZWE049	Genetic Resources and Biotechnology Institute-Department of Research and Specialist Services	4	0.0%	99.9%	Not listed	326	0
ALB026	Plant Genetic Resources Center	3	0.0%	99.9%	2	0	2
MEX287	Banco de Germoplasma de Especies Nativas de Oaxaca (BAGENO)	3	0.0%	99.9%	Not listed	0	0
TUR034	Field Crop Central Research Institute	3	0.0%	100.0%	3	0	0
AUT025	Referat Pflanzengesundheit und Spezialkulturen	2	0.0%	100.0%	2	0	1
AZE003	Research Institute of Crop Husbandry	2	0.0%	100.0%	Not listed	0	0
AZE004	Institute of Botany	2	0.0%	100.0%	Not listed	0	0
CZE079	Research Institute of Landscaping and Ornamental Gardening	2	0.0%	100.0%	Not listed	0	2
EST019	Estonian Crop Research Institute	2	0.0%	100.0%	2	0	2
GEO013	Niko Ketskhoveli Institute of Botany	2	0.0%	100.0%	Not listed	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
LTU001	Lithuanian Institute of Agriculture	2	0.0%	100.0%	2	0	2
MEX367	Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro	2	0.0%	100.0%	Not listed	0	0
MKD001	Faculty of Agriculture, University Ss. Cyril and Methodius	2	0.0%	100.0%	Not listed	0	0
MRT002	Centre National de Recherche Agronomique et de Développement Agricole	2	0.0%	100.0%	Not listed	0	0
UKR019	Research Station of Medicinal Crops	2	0.0%	100.0%	2	0	0
USA151	National Arboretum-Germplasm Unit, USDA/ARS	2	0.0%	100.0%	Not listed	0	0
USA476	National Tree Seed Laboratory	2	0.0%	100.0%	Not listed	0	0
UZB006	Uzbek Research Institute of Plant Industry	2	0.0%	100.0%	Not listed	0	0
ARG1352	Atar Semillas Hibridas S.A.	1	0.0%	100.0%	Not listed	0	0
AUT001	Austrian Agency for Health and Food Safety	1	0.0%	100.0%	1	0	0
BGD028	Bangladesh Institute of Nuclear Agriculture (BINA)	1	0.0%	100.0%	Not listed	0	0
CHE001	Agroscope Changins	1	0.0%	100.0%	1	0	1
CUB014	Instituto de Investigaciones Fundamentales en Agricultura Tropical	1	0.0%	100.0%	Not listed	0	0
ECU167	Banco de Germoplasma de la Universidad Técnica Particular de Loja	1	0.0%	100.0%	Not listed	0	0
ECU330	Estación Experimental Tropical Pichilingue	1	0.0%	100.0%	Not listed	0	0
ESP009	Consejo Superior de Investigaciones Científicas. Misión Biológica de Galicia	1	0.0%	100.0%	Not listed	0	1
ESP109	Junta de Castilla y León. Instituto Tecnológico Agrario de Castilla y León. Centro de Investigación de Zamadueñas	1	0.0%	100.0%	1	0	1
FRA098	Station de la Réunion, CIRAD-FLHOR	1	0.0%	100.0%	1	0	0

Institution Code	Institution name	Number of accessions	Percent of total	Cumulative percent	Number of accessions in long term storage (-18-20 C)	Number of accessions included in MLS (from Plant Treaty GLIS)	Number of accessions included in MLS (from genebank collections databases)
GRC044	Balkan Botanic Garden of Kroussia, Institute of Plant Breeding and Genetic Resources	1	0.0%	100.0%	Not listed	0	0
HRV021	Agricultural Institute Osijek	1	0.0%	100.0%	Not listed	0	0
HRV053	Center for Seed and Seedlings	1	0.0%	100.0%	1	0	0
KGZ040	Bank-Laboratory of Plant Genetic Resources of the KR	1	0.0%	100.0%	1	0	1
PHL008	Bureau of Plant Industry, Department of Agriculture	1	0.0%	100.0%	Not listed	0	0
POL101	Research Institute of Horticulture	1	0.0%	100.0%	Not listed	0	1
ROM023	University of Agricultural Sciences and Veterinary Medicine Timisoara	1	0.0%	100.0%	Not listed	0	0
UGA528	Uganda National Genebank	1	0.0%	100.0%	Not listed	17	0
UKR017	Institute of Agriculture of the Woodlands	1	0.0%	100.0%	Not listed	0	0

Supplementary Table 2: Full list of taxonomic names in *ex situ* genetic resource collections, in descending order by number of accessions conserved. Germplasm data from Genesys and FAO WIEWS (2024). Available here.

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