Food and Agriculture Organization of the United Nations

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture

Conservation in field genebanks

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Foreword

The international development community and governments are striving to achieve the Sustainable Development Goals (SDGs), including the eradication of hunger, by 2030. The imperative of generating and disseminating the solutions that work for farmers as means to achieve the SDGs provides the backdrop for FAO's Strategic Framework 2022-2031. The Strategic Framework aims to transform current sub-optimal agricultural and food systems to become more efficient, inclusive, resilient and sustainable as envisaged in its four aspirations: better production, better nutrition, a better environment and a better life.

With about 80 percent of food being plant-based, these efforts will benefit greatly from sustainable crop production systems, which generate increased yields of nutritious food with fewer external inputs than are currently the case, even under worsening climate change scenarios. One critical element of such systems is a diverse suite of progressively superior crop varieties that are input use-efficient, nutritious, adapted to target agroecologies, and resilient to biotic and abiotic stresses. Plant breeders need access to the widest possible spectrum of the sources of heritable variations in order to breed such crop varieties. Plant genetic resources for food and agriculture (PGRFA) – which include improved crop varieties, farmers' varieties/landraces and the wild relatives of crops – are the sources of such variations. The safeguarding of characterized and documented PGRFA in genebanks is a reliable means to ensure their availability to current and future generations – both for direct use and for research and plant breeding.

FAO and partners have been cognizant of the critical importance of effective genebank operations to sustainable crop production systems. In addition, in recognition of the global interdependence on PGRFA, facilitated through the exchange of germplasm, the need for the harmonization of genebank procedures has always been at the forefront of FAO's work on the conservation and sustainable use of PGRFA. This was why FAO, through

its Commission on Genetic Resources for Food and Agriculture, published the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (Genebank Standards) in 2014. The Genebank Standards provide international standards for *ex situ* conservation of PGRFA in seed genebanks, field genebanks, *in vitro* culture and cryopreservation.

Deemed a seminal reference material, one of the feedbacks provided by genebank practitioners was that the utility of the Genebank Standards would be enhanced through the development of companion volumes that detail the action steps of the genebank workflow in a sequential manner and provide guidance on the complex steps and decisions required. In response to this feedback, FAO developed the *Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation in field genebanks.* In addition, the *Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation of orthodox seeds in seed genebanks* and the *Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation via* in vitro *culture* have also been developed.

These companion volumes, prepared in an easy to understand format, will be useful for genebank technicians as operational handbooks; for genebank managers as streamlined instructional materials and for all interested in genebank operations, a handy reference material.

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Preface

The *ex situ* conservation of plant genetic resources for food and agriculture (PGRFA) in genebanks is aimed at safeguarding them for use by current and future generations – both directly by end users and as materials for research and plant breeding. Genebanks, therefore, ultimately contribute to sustainable crop production systems and hence, food security and nutrition. However, genebanks must be managed effectively in order to conserve these resources in optimal conditions and making them available for use.

Genebanks also play a major role in fostering global collaboration on PGRFA through germplasm exchange, including across national boundaries. The *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (Genebank Standards), published in 2014, aimed at the harmonization of genebank operations, i.e. the storage of the accessions, their characterization and evaluation and the documentation of associated data, across genebanks and countries. The Genebank Standards set the benchmark for current scientific and technical best practices.

Addressing an identified need for the articulation of the stepwise activities of routine genebank operational workflows, the *Practical guide for the application of the Genebank Standards for Plant Genetic Resources: Conservation in field genebanks* was developed. Endorsed by FAO's Commission on Genetic Resources for Food and Agriculture at its Eighteenth Regular Session in 2021, this practical guide presents the information contained in the Genebank Standards in a format that presents the action steps of genebank workflow in a sequential manner. The series of interrelated operations presented, are based on the underlying principles of genebank management, namely: identification of accessions; maintenance of viability; maintenance of genetic integrity during storage and regeneration; maintenance of germplasm health; physical security of collections; availability, distribution and use of germplasm; availability of information; and proactive management.

The sections included in this practical guide are: choice of location of the field genebank; acquisition of germplasm; establishment of field collections; field management; regeneration and propagation; characterization; evaluation; documentation; distribution; safety duplication; and security and personnel. A summary diagram of the associated workflow and activities supports each of these operations. An additional section considers the suggested infrastructure and equipment for designing or modifying the facilities of a field genebank. A final section provides a list of references to provide guidance and/or technical background on field genebank operations and management. An annex identifies the potential risks associated with the different genebank operations and their respective proposed preventive measures.

This practical guide is part of a series of publications conceived as companion volumes to the Genebank Standards aimed at facilitating their more widespread application. Genebank managers may use the practical guide as a basis for the development of standard operating procedures, quality management systems or, simply, as a handbook.

1. Introduction

Mango field collection in flower, India

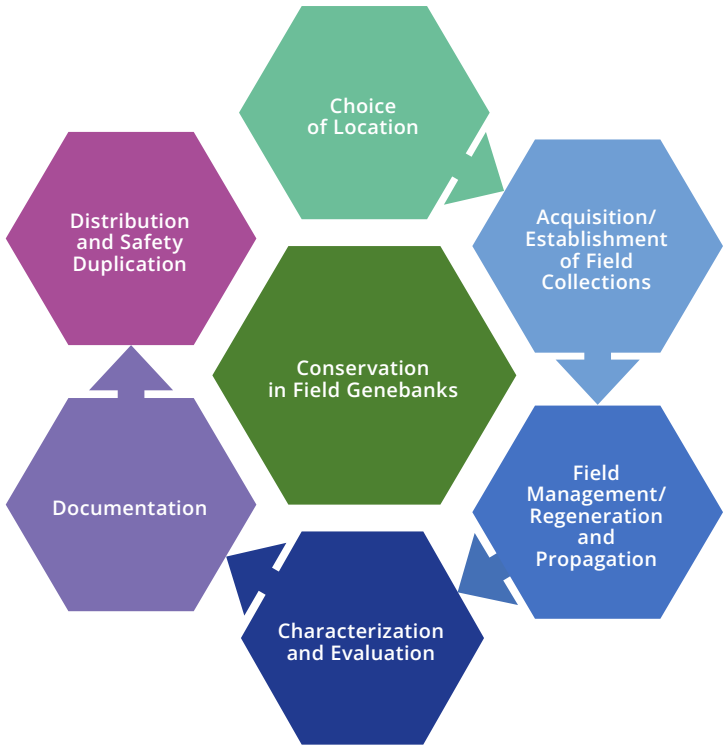
Many field and horticultural crops as well as agroforestry species are difficult or impossible to preserve as seeds because they only produce recalcitrant seeds with short lifespans in seed storage, because seed production may take many years (as is the case for many tree species) or because they do not produce seeds at all and can only be vegetatively propagated. Other examples include males of dioecious species and rare plants that are under threat from overgrazing and for which there is no time to produce seeds before the population totally vanishes. Major crop groups kept in field genebanks include: root and tuber crops such as potato, cassava, yams, sweet potato, taro and bananas; subtropical and tropical shrub and tree species such as coffee, cocoa, rubber, coconut, peach palm, breadfruit, mango and citrus; many temperate fruit trees such as grape, apricot, apple, cherry and pear; perennial grasses such as sugar cane; and alliums (garlic, shallot). Additionally, although some of the crops conserved in this way are sexually fertile, it is often not convenient to propagate them from seed owing to their genetic heterozygosity; breeders and horticulturalists commonly require uniform clones. Conservation in field genebanks offers an option for these species.

In field genebanks, plant genetic resources are kept as living plants that undergo continuous growth and require constant maintenance. As plants are grown in the field, germplasm health issues are highly relevant and regular disease monitoring and testing, together with application of control measures, are essential in order to maintain plants that are free of diseases. However, field genebanks provide ready and easy access to the conserved material for characterization, evaluation, research and training, and also to germplasm users who can visit the collections and examine the plants during vegetative or reproductive stages. Vegetative materials are readily available for germplasm distribution.

Field genebanks are underpinned by the same principles as other genebanks, namely identification of accessions, maintenance of viability, maintenance of genetic integrity during storage and regeneration, maintenance of germplasm health, physical security of collections, availability, distribution and use of germplasm, availability of information and proactive management (FAO, 2014: Chapter 2).

Conservation in field genebanks can be broken down into a series of interrelated operations (Figure 1). This practical guide for conservation in field genebanks presents practices and activities[1] critical to each operational area (Table 1). It outlines workflows for routine field genebank operations (Figure 2), and supports the application of the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (Genebank Standards) (FAO, 2014).[2] The purpose of this guide is to present the information contained in the Genebank Standards in a format that details the

Figure 1. Major operations for conservation in field genebanks



1 Practices and activities follow best practices as outlined in the Genebank Standards.

2 All standards referenced throughout the document are described in the FAO Genebank Standards.

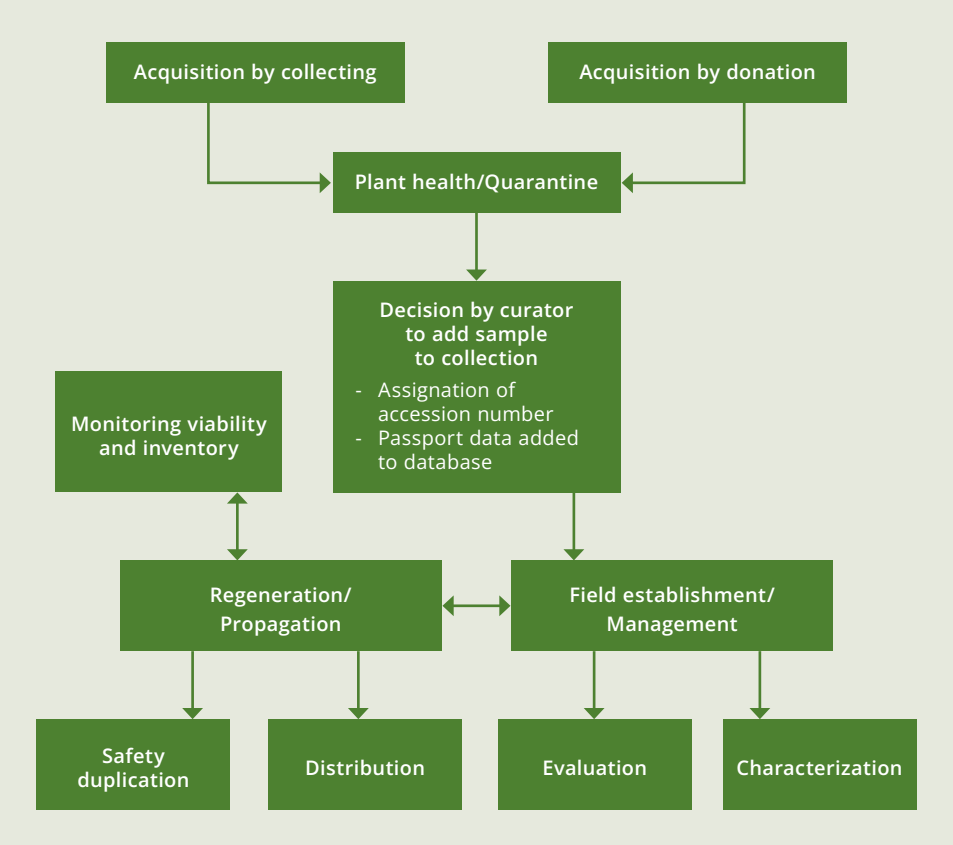
different actions of the genebank workflow in a sequential manner and thereby facilitate more widespread application of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis for developing standard operating procedures (SOPs) (e.g. IITA, 2012) and quality management systems (QMS) (CGIAR Genebank Platform, 2021) for conserving germplasm collections, defining in detail how to carry out each activity.

This booklet only provides general guidance on the complex steps and decisions required when operating a field genebank. Each genebank will have its own special circumstances, and the efficient management of particular collections will require careful consideration and procedural adjustments based on experience. For detailed technical specifications of the steps outlined in this guide, the genebank staff will need to consult various sources of information, a few of which are referenced in this booklet.

Table 1: Underlying principles and related genebank operations for field genebanks

Genebank principle	Summarized genebank operations
Identity of accessions	Passport data collected and recorded Taxonomic identity verified Permanent and unique accession number assigned and used in all documentation Accessions handled carefully to avoid mixing, and all samples labelled and tracked through genebank operations and in the field or greenhouse/ screenhouse
Maintenance of viability	Best practices followed and timing optimized during collection, processing, field introduction and cultural practices, regeneration and transportation Field conditions optimized and monitored Plant health monitored regularly Regeneration and propagation undertaken when necessary
Maintenance of genetic integrity	Collection and maintenance of samples conducted in a manner that ensures they represent the original population as fully as possible Field site situated in location that minimizes gene flow and genetic contamination Best practices followed in collection, processing, field introduction and cultural practices, regeneration, propagation and transportation
Maintenance of germplasm health	Quarantine procedures undertaken when needed Best practices followed in collection, processing, field introduction and management, growing, regeneration and transportation Pests and diseases monitored and managed
Physical security of collections	Risk management strategy developed and implemented Field site situated in secure location Appropriate genebank infrastructure in place and maintained Accessions safety duplicated and safety backed up
Availability and use of germplasm	Germplasm acquired and distributed according to legal and phytosanitary requirements Sufficient inventory and efficient and timely dispatch of samples ensured Relevant documentation provided to recipients of genebank material
Availability of information	Genebank information management system in place Passport and accession-management data secured by regular data backups Passport and other relevant data available and accessible to external users, as far as possible
Proactive management of genebanks	Standard operating procedures developed and available to staff Data and information generated during genebank activities available to managers and staff Well-trained staff employed and protected by occupational safety and health measures Genebank staff capacities kept up to date, and training provided as necessary

Figure 2. Flow of germplasm in a field genebank
Note: Each step is associated with proper documentation.



2. Choice of location of the field genebank

Grape field collection, Armenia

The genebank should have a documented policy and/or procedure, as applicable, in place for selecting and acquiring land for the field genebank, including a checklist of requirements and regulations.[3]

✔ **The site of the field genebank has agroecological conditions as similar as possible to the environment where the conserved plant materials originated.[4]**
It is important to choose a field site with climate, elevation and soil conditions that provide appropriate conditions for good adaptation and growth of the plants. This will minimize the risk of plant losses due to poor adaptation, which would occur if the original environments were substantially different from that of the genebank location. Commercial production of the target crop(s) nearby may be a useful indicator of suitable growing conditions.

✔ **The site is in a location that minimizes risks from natural and human-made disasters.[5]**
Safety of the collection is a priority of every genebank. It is necessary to undertake a risk assessment to ensure that natural and human-made calamities do not threaten the physical safety of the collections at the selected genebank site. Safety considerations to consider when choosing the location include:
- maintaining a safe distance of at least 10 km radius from active volcanoes to avoid damage from lava flow and rocks;
- avoiding areas that are frequently in the path of hurricanes, typhoons or snow avalanches;

[3] See Figure 3 at the end of this section for a summary diagram of the workflow and activities for the choice of location of the field genebank.

[4] Standard 5.1.1.

[5] Standard 5.1.2.

- avoiding areas close to human settlements known to be affected by civil strife; and
- choosing a location where the target crop has not been grown recently, in order to avoid heavy infestation of major diseases or pests that might cause plant losses or make disease and pest management very costly.

✔ **The site minimizes risk of gene flow and contamination from crops and wild populations of the same species and related species with which the conserved species can cross-pollinate, thereby maintaining genetic integrity.[6]**
Outcrossing species that are used to produce seeds for distribution require a safe isolation distance to avoid potential impact of gene flow and contamination from nearby commercial crop stands or wild populations of the same species.

✔ **The site is secure over the long term (minimum of 50 years) based on written, guaranteed renewal or gazetted land tenure.[7]**
Establishing a field genebank with tree species or shrubs is a long-term investment. It is important to investigate the development plan for the area, as sites close to a town or city may be needed for other activities in the future.

✔ **If possible, the site provides sufficient space for future expansion, as new accessions might need to be added after the establishment of the field genebank.**

✔ **The land area selected for the field genebank is suitable for using mechanized mulching and both fertilizer and pesticide applications.**
It is important that the site has easy access to a water source for necessary pesticide applications and, as required, for supplemental irrigation.

✔ **The site is within easy transport distance for curational staff and field labourers[8] and has access to facilities for propagation and raising plants in nurseries.**
Easy physical access to the field genebank site facilitates field and plant management and regular monitoring.

6 Standard 5.1.3.

7 Standard 5.1.4.

8 Standard 5.1.5.

✔ **All related data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
Data to consider include geographic location and boundaries, slope, climate information and any legal agreements on land tenure, etc. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

Figure 3. Summary diagram of the workflow and activities for the choice of location of the field genebank

3. Acquisition of germplasm

Taro cuttings, Fiji

The genebank is recommended to have documented policies and/or procedures, as applicable, for acquiring germplasm that include abiding by legal, phytosanitary and other regulations and requirements.[9]

✔ **Decisions to accept germplasm into a genebank's collection are guided by the institute's acquisition policy.**

The development of an acquisition policy ensures that collections remain manageable and meet users' needs (Guarino, Rao and Reid, eds. 1995).

- Genebank curators may interact with breeders, botanists and other scientists before deciding on new acquisitions. Institutes may also have a crop-specific or general advisory committee in place.
- The health and viability status of collected or donated samples, availability of passport information (taxonomic identity, origin of the germplasm, etc.) and sample "uniqueness" (to avoid unnecessary duplicates) should also be considered in the decision-making process.

✔ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.[10]**

The process of germplasm acquisition is governed by national and international regulations such as phytosanitary/quarantine laws, the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) or the Convention on Biological Diversity (CBD) for genetic resources access (FAO, 2014).

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9 See Figure 4 at the end of this section for a summary diagram of the workflow and activities for the acquisition of germplasm.

10 Standard 5.2.1.

- The genebank should communicate with the National Focal Points for the Treaty or other designated authorities on questions concerning germplasm acquisition.

✔ **A permanent and unique accession number is assigned to each sample added to the genebank collection.**
Once the curator decides to accept a sample into the genebank, a unique accession number must be assigned.
- A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty (FAO, 2021a). Both the accession number and the DOI remain with all material derived from the accession during all genebank handling.
- If donated material has an accession number assigned by the donor organization, a DOI or both, keep these as alternative identifiers in the passport data. This is a critical means of ensuring the unambiguous association of information with the material.

✔ **Germplasm added to the genebank collection is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[11]
It is recommended that all samples, whether obtained through collection missions or donation from other institutes, be accompanied by the associated data detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (Alercia, Diulgheroff and Mackay, 2015).
- The association of data with the single accession must be clear, for example through the use of accession numbers and/or DOI.

✔ **All acquisition data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
Consider the use of electronic devices to avoid transcription errors and for ease of uploading. Otherwise, the use of indelible ink (or pencil) and clear, legible writing are necessary when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

3.1 Germplasm acquired through collecting missions

✔ **A clear strategy for germplasm collecting missions is developed according to the institute's mandate.**
Setting collection priorities prior to any collection mission is essential. It is recommended that a collecting proposal be developed that clearly states the purpose of the collecting mission, the target location and the methodology. It may be appropriate and useful to:

[11] Standard 5.2.2.

- emphasize the importance of conducting inventories and gap analyses to prevent duplicates and of having a clear strategy for collecting missions that considers national inventories and gap analyses;
- establish a collaboration with an institute or experts from the targeted area and abide by regulations for collecting in that area; and
- plan the mission well in advance in order to ensure best practices and compliance with regulations and requirements.

✔ **Collected germplasm is legally acquired and accompanied by all relevant documentation.[12]**

The process of germplasm acquisition is governed by national and international regulations. The following information could assist in ensuring compliance with these regulations:

- The genebank should communicate with the appropriate designated authorities when there are questions regarding germplasm acquisition.
  - For collecting missions in other countries, it may be necessary to contact the National Focal Points for the Treaty or other designated authorities for germplasm acquisition.
  - For collecting missions in the genebank's country, it may be necessary to contact the national competent authority in order to ensure understanding of and compliance with national and local regulations.
- Collecting permits from national, regional or local authorities, as appropriate, may be required for collecting crop wild relatives or semi-domesticated germplasm in natural populations *in situ*.
- When collecting from farmers' fields/stores or community areas, including some natural habitats, prior informed consent (PIC) may be required and mutually agreed terms (MAT) (see CBD, 2018) determined, according to relevant national, regional or international laws and regulations.

✔ **The genebank abides by national, regional and international phytosanitary and any other import regulations and requirements from the relevant authorities.[13]**

When germplasm is moved there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may help mitigate such risks while ensuring compliance with regulations and requirements:

- for materials collected in another country, obtaining a phytosanitary certificate from the provider country and an import permit from the relevant authorities in the genebank's country (see IPPC, 2021);
- passing samples through the relevant quarantine process before they are transferred to the genebank, if required; and
- handling collected materials in containment or in an isolated area, according to the advice of the national phytosanitary authority.

12 Standard 5.2.1.

13 Standard 5.2.1.

✔ **Collecting missions are scheduled at the optimum stage of maturity/growth and propagules are collected from visibly healthy plants, devoid of disease and insect pest infestations or other damage.[14]**

It may be necessary to engage a local expert if the species is not known to genebank staff in order to ensure the quality and viability of the collected sample. Seasonality is a consideration for the collecting of bulbs, tubers and woody species. Genebank staff should consult specific sources of information depending on the target species to be collected.

✔ **Propagules are collected from an appropriate number of individual plants[15] while avoiding the depletion of the natural population targeted for collecting.**

The breeding system of the target species may be taken into consideration in order to define the number of plants to sample within a population and the type and size of the propagule (see SGRP-CGIAR, 2011).[16]

- It is recommended to harvest from at least 30 individuals for cross-fertilizing species and 60 individuals for autogamous species, if possible.
  - If collecting recalcitrant seeds, the sample size for collecting will usually be limited compared to orthodox seeds. Nevertheless, all attempts should be made to maximize the genetic diversity of the target population.
  - For roots and tubers, collect a minimum of four propagules for each sample, more if culturing techniques for the species are not reliable (Dansi, 2011).
  - If collecting woody stems, increase sample size to allow for any problems (and therefore losses) in decontamination. Approximately 5–10 cuttings/propagules per plant has been recommended (see Thompson, 1995).
- Note: Collecting *in vitro* materials offers an alternative for germplasm collection and transport, and is particularly useful for species that are vegetatively propagated and for those with recalcitrant seeds or embryos, which deteriorate rapidly. However, transportation times will still have to be minimized.
  - Explants collected *in vitro* are often surface-decontaminated using 70 percent ethanol, followed by NaOCl or commercial bleach that generally contains about 3 percent active chlorine. Alternative sterilants, such as dilute solutions of 0.5–2 percent (weight/volume) calcium hypochlorite, may also be used. After decontamination, the explant is usually trimmed to a final size for transport, including removal of the dead zones caused by the sterilizing solution penetrating the cut surfaces. See Pence and Engelmann (2011) for additional guidance on *in vitro* collecting techniques.

[14] Standard 5.2.3.

[15] See Genebank Standards (Chapter 5, section 2).

[16] The Crop Genebank Knowledge Base provides very useful information on collecting.

✔ **Collected samples are labelled and are not mixed during handling.**
Use indelible ink or computer-generated labels (preferably with barcodes), if possible, on the propagule packet to label the sample. Placing labels both inside and outside a seed packet is a good practice. Protecting inside labels from deterioration is useful if the seed/plant material is not dry. It is recommended to keep a journal with all collection numbers assigned to each samples and additional information, as required.

✔ **Collected germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.[17]**
A standardized collecting form is helpful for collecting the associated data for each sample obtained. Each sample is assigned a collection number so the samples can be linked to the collected information. Collecting the following information may be considered:

- taxonomic identification at species and intraspecific levels, if possible, plant population type, habitat and ecology, soil conditions at the collecting site, GPS coordinates and photo images in order to provide curators and users of the germplasm with an understanding of its original context;
- associated data for each sample obtained as detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (Alercia, Diulgheroff and Mackay, 2015; see Box 1); and:
- information on the origin of the germplasm, traditional knowledge, cultural practices, etc. if collecting from farmers' fields/stores.
- Note: For any herbarium voucher specimen obtained as a reference from a population (for example wild species), it is important to use the same collection number as that of the collected sample and associate it with the accession number in the database.

Box 1: Minimum passport data

As a minimum, collecting forms should contain:

- Collection number
- Collecting institute name/code
- Taxon name, as detailed/specific as possible
- Common crop name
- Location of collecting site
- Latitude of collecting site
- Longitude of collecting site
- Elevation of collecting site
- Date of collecting
- Biological status (wild, weedy, landrace, etc.)

[17] Standard 5.2.2.

✔ **The period between collecting, processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.**[18]
Clonal stocks do not retain viability for a long period of time and vegetative propagules decay easily and quite fast. Transport in tropical countries, where high temperatures and humidity prevail and where transport may be difficult, slow and uncertain, can be the most challenging. Under such conditions, special care must be taken to ensure that samples are not left in the sun and are stored under shade at all times.

✔ **The choice of packaging material and transport allows for safe and timely delivery.**
The time needed for document processing, shipment/transit time and conditions (temperatures and/or humidity) are generally taken into account in order to ensure that the material reaches the destination genebank in good condition. The following considerations could decrease the risk of germplasm loss after collecting missions:

Packaging

- Precautions should be taken to avoid risks of fungal or insect attacks during shipment.
  - If a pest has been observed and correctly identified, it may be necessary to apply pesticide before packing. Avoid any unnecessary chemical treatment, as it may be harmful to the collected samples.[19] If treatments are applied, declare them on each package and in accompanying documentation.
- For recalcitrant seeds, it is important that water content be maintained upon collecting and during transport by maintaining high relative humidity (RH) in the storage containers.
  - Where possible, recalcitrant seeds are best transported within the fruits, both for protection and to avoid dehydration.
  - For species with very large fruits or fruits that can be easily damaged during transport, extracting seeds and surface disinfection before packaging should minimize fungal proliferation.
- Scions and other vegetative material are best packed in sterile cotton or other suitable material in a perforated plastic bag to ensure sufficient air exchange.
- Rigid cushioned envelopes or insulated packaging should protect samples from crushing by mechanical mail sorters and deterioration.
- If available, *in vitro* plantlets are a safe way of moving germplasm. *In vitro* collected samples should be placed in sterile transparent watertight sealable plastic vials and packed firmly, but not too tightly, in a box or carton, with addition of crumpled paper or polystyrene material to protect against shocks.

[18] Standard 5.2.4.

[19] Many of the fruits of plants with recalcitrant seeds are contaminated with fungi even when they are not visible. Surface disinfection must therefore be carried out prior to transport.

Transport

- For long transit times by road, periodic aeration of the collected material may be necessary as a precaution against viability loss.
- Sending shipments using the fastest means possible, by airfreight or courier, should avoid long exposure to adverse environmental conditions and deterioration of sample quality.
- Continuous tracking of the package, if possible, will ensure genebank staff are prepared to process the samples upon arrival at the genebank.
- Note: For some crops, such as *Musa* and cocoa, shipment of material through transit or quarantine centres in non-producing third countries may be the best solution.

✔ **All incoming material is checked for damage/contamination in a designated reception area (e.g. plant health unit) and processed in a way that does not alter the physiological status.[20]**

- Low-quality or contaminated plant materials are not planted directly in the field.
- Decontamination activities, such as treating samples with a surface disinfectant agent, are used to remove all adherent microorganisms, taking into account any decontamination treatment given prior to packaging and transport.
- Quarantine measures are applied, as necessary.

3.2 Germplasm acquired through transfer/donation

✔ **Donated germplasm is legally acquired and accompanied by all relevant documentation.[21]**

- If the donating institute is from a country that is a signatory to the Treaty and the donated germplasm includes crops or species listed under Annex 1 of the Treaty (FAO, 1995), it is necessary to use a Standard Material Transfer Agreement (SMTA) (FAO, 2021b, c).
- If the donating institute is from a country that is not a Contracting Party to the Treaty or if the germplasm is not covered under Annex 1, a Material Transfer Agreement (MTA) is usually used (e.g. AVRDC, 2012), though a SMTA could also be used.
- For donations from institutions, plant breeders or other germplasm providers without an MTA, it may be useful for the genebank to have a donor agreement spelling out the conditions of germplasm transfer to the genebank.

[20] Standard 5.2.5.

[21] Standard 5.2.1.

✔ **Donated germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[22]

- It is recommended to request donors that samples be accompanied by the associated data detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (Alercia, Diulgheroff and Mackay, 2015; see Box 1).

✔ **The genebank abides by national, regional and international phytosanitary and any other import regulations and requirements from the relevant authorities.**

When germplasm is moved there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may help mitigate such risks while ensuring compliance with regulations and requirements:

- for materials from another country, obtaining a phytosanitary certificate from the provider country and an import permit from the relevant authorities in the genebank's country (see IPPC, 2021); passing samples through the relevant quarantine process before they are transferred to the genebank, if required; and
- handling donated materials in containment or in an isolated area, according to the advice of the national phytosanitary authority.

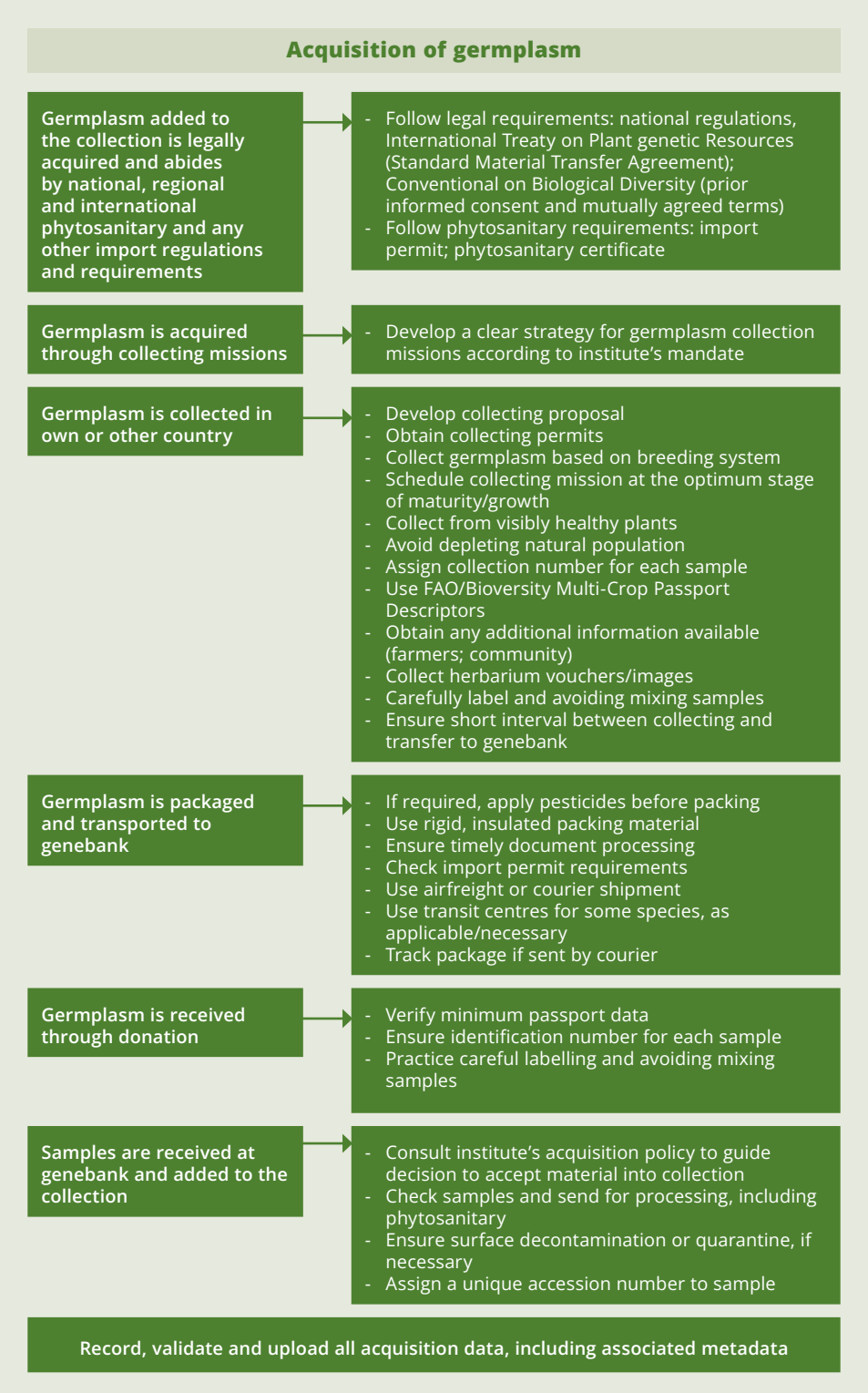
✔ **All incoming material is checked for damage/contamination in a designated reception area (e.g. plant health unit) and processed in a way that does not alter the physiological status.**[23]

- Low-quality or contaminated plant materials are not planted directly in the field.
- Decontamination activities, such as treating samples with a surface disinfectant agent, are used to remove all adherent microorganisms, taking into account any decontamination treatment given prior to packaging and transport.
- Quarantine measures are applied, as necessary.

[22] Standard 5.2.2.

[23] Standard 5.2.5.

Figure 4. Summary diagram of the workflow and activities for the acquisition of germplasm



4. Establishment of field collections

©FAO/A. Noorani

Yam collection, Indonesia

The genebank should have documented policies and/or procedures, as applicable, on field preparation, introduction of collections into field and other living plant collections, and the maintenance of inventory and field maps.[24]

✔ **The field is prepared to further safeguard the collection.**
In addition to choosing a site that minimizes risks from natural and human-made disasters,[25] it is important to physically prepare the site to further protect the collection. Such measures may include:

- establishing firebreaks if bushfires are a known risk;
- installing fencing and hiring security guards to prevent vandalism, theft and damage by large animals;
- installing insect netting and using caging to prevent insect, bird and small-mammal damage;
- inserting hedgerows on the outside of field plots to help prevent pesticide drift and provide security as an alternative to (or as well as) fencing; and
- installing an irrigation system to water the plants in the case of drought or when there is high demand (e.g. establishment, fruit-setting period).

✔ **Appropriate land preparation for successful establishment of field collections is carried out.**
The land should be prepared in a way that takes into account species' needs. Such activities may include tilling weeds or herbicide application, deep ploughing and corrective measures for acidic or alkaline soils, etc.

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[24] See Figure 5 at the end of this section for a summary diagram of the workflow and activities for the establishment of field collections.

[25] See section on choice of location of the field genebank.

✔ **Design of fields and plots, including individual plot layout, creation of electronic and printed maps, as well as use of barcodes and field labels, is as an important element of the establishment phase of the field genebank.**
Proper planning and accession identification are essential for maintaining genetic identity. It is important to:

- prepare a field map that shows the exact location of each accession in the plot,[26] maintaining both hard and electronic copies (if possible) and updating it regularly; and
- ensure that each plot is demarcated with two clearly written weather-resistant indelible tags or stakes.
- **Note:** Vegetatively propagated annual crops, such as alliums, do not require a field layout and field plan that is fixed in time. However, crop rotation is essential and will require proper scheduling and additional free space.

✔ **Appropriate placement of accessions is considered at the plot design phase to allow for proper growth of individual plants.**
Considerations when planning the layout of the field plots include:

- the optimum location of individual accessions for effective management of the field collection and ease of monitoring, characterization and evaluation;
- the need for irrigation structures and ease of maintenance;
- temperature, soil moisture levels, soil type, etc.; and
- specific microclimate requirements, such as high or low shade intensity.

If space allows, reference accessions should be planted in the same field to facilitate identification.

✔ **Utilize appropriate spacing among plants within each accession to allow for proper growth of individual plants.**
It is important to consider the growth habit and the adult size of the plants when calculating the size of the plots. It will also be beneficial to establish and follow recommended isolation distances to hinder cross-pollination, when needed.

✔ **A sufficient number of individuals are planted to capture genetic diversity and ensure the safety of each accession.[27]**
To determine the number of individuals to be planted per accession it will be necessary to differentiate between annual, biennial and perennial crops and between species that are propagated by seeds and those that are propagated vegetatively. In particular, the following considerations are suggested:

- When the species is propagated by seeds, the number of plants needs to be sufficiently large to represent the within accession diversity.[28]

[26] Standard 5.3.2.

[27] Standard 5.3.1.

[28] Guidelines can be extrapolated from germplasm collection practices.

- Due to the uniformity of vegetatively propagated species, only a small number of plants are necessary in order to represent the genetic diversity within the accession and to ensure its security.[29]
- For dioecious species, such as holly, asparagus and date palm, it is important to plant a suitable number of male/female parents.

✔ **Healthy material and vigorous parts of the plant are utilized for propagation and planting.**

Strict control of plant introductions into the field should be exercised to avoid introduction of diseases and pests. For those species that are propagated through grafting, it is particularly important to select rootstocks that are virus-free and adapted to the environment. The choice of rootstock has an impact on the performance and specific traits of the scion, and this will influence the characterization and evaluation data of the accessions.

✔ **Cultural practices provide optimum conditions for plant establishment.[30]**

Appropriate cultivation techniques, specific to the target species, are essential for successful establishment and efficient maintenance of the field genebank and to ensure the optimum health and longevity of the plants. Such practices include:

- having a clear understanding of established planting times for species/species groups (e.g. FAO, 2021d);[31]
- using rootstocks adapted to local conditions;
- providing higher shade intensity and good drainage at the field genebank site to simulate natural growing conditions in the case of crop wild relatives that originated in natural forests:
  - for those species requiring shade trees, it is important to choose the shade trees according to the requirements of the species and local conditions;
- practicing weed control for rapid and vigorous plant growth;
- monitoring and treating for pests and diseases;
- exercising strict control of plant introductions into the field genebank to avoid introduction of diseases and pests; and
- using isolation cages or pollination-control measures for propagation purposes if needed.

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[29] In general, approximately 3–6 plants per accession for most vegetatively propagated species are maintained. For root and tuber crops, including annuals, biennials and perennials that require frequent or periodic harvesting and replanting, the number of plants may range from 8 (taro) to 50 plants (shallot, garlic) per accession.

[30] Standard 5.3.3.

[31] Note: FAO has published crop calendars for Latin America and Africa that are helpful in this regard.

- ✔ **All collection establishment data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
  Data to consider include field and plot design, individual plot layout, electronic and print maps, barcodes, planting/grafting dates, number of plants established for each accession, type of propagation (cuttings, tubers, corms, bulbs, seeds), method of planting, cultural practices (spacing, weeding, irrigation, fertilizer, pesticide application, etc.) used during establishment and management of the propagated material. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

Figure 5. Summary diagram of the workflow and activities for the establishment of field collections

5. Field management

©FAO/B. Furman

Hazelnut collection, Azerbaijan

The field genebank should have a documented policy and/or procedure, as applicable, for conservation of field and live plant collections, including step-by-step instructions for cleaning, field management processes, cultural practices, identity verification and monitoring of germplasm in the collections.[32]

✔ **Cultural practices necessary for optimum plant growth and maintenance are followed.[33]**

Appropriate cultivation practices are essential to ensure optimum plant growth and longevity of the plants. After establishing the collection, it is important to continue providing favourable conditions for the growth and survival of the field collection. Cultural practices to consider include:

- providing water in the case of drought or during periods of high demand (fruit-setting period);
- adjusting fertilizer application to plant types;
- practicing weed control, as necessary;
- utilizing other measures, such as frost and/or hail protection, as needed, to ensure fruit production;
- providing netting to protect from birds, if needed;
- conducting regular pruning to keep the size of plants within acceptable limits within the plantation and, in the case of trees, to shape their canopy and allow sufficient light penetration for optimum fruit growth;
- providing support structures (trees, wooden sticks, wires, etc.) for species that grow as vines (vanilla, many beans, cucurbits, etc.); and
- carrying out regular monitoring of growth and performance of accessions.

[32] See Figure 6 at the end of this section for a summary diagram of the workflow and activities for field management.

[33] Standard 5.4.2.

✔ **The genetic integrity of the collection is maintained.**
It is essential that the field collection is managed in a way that prevents any contamination among accessions, including prevention of gene flow from neighbouring plants and mixing of accessions as a result of rogue plants.[34] Best practices include:

- rogueing out any involuntary seedlings;
- maintaining sufficient distance or barrier crops between accessions of cross-pollinated crops in cases where seeds will be distributed;
- for annual and biennial species, it is important to:
  - monitor field collections regularly to ensure that each accession and each plant within the accession is properly identified;
  - periodically verify accession labels with the field map;
  - compare individual plants within each accession to plot plans; and
  - periodically verify the identity of each accession using morphological and molecular markers when possible.

✔ **A system is in place for the routine monitoring and correct identification of all associated pests and diseases affecting the range of crops that are included in the collection.[35]**
Routine monitoring of the collections for pests and diseases will help avoid outbreaks that damage the collection. It may be useful to collaborate with specialists such as phytopathologists, including virologists and nematologists, to ensure proper identification and obtain advice on control measures for diseases and pests.

✔ **Disease prevention and control measures are carried out in a timely manner.**
The safety of the collection requires that disease prevention and control measures are undertaken, for example:

- keeping susceptible plants in insect-proof screenhouses to protect them against vectors transmitting virus diseases;
- ensuring that tools and farm implements, footwear and soil for the nursery are properly sanitized;
- removing any infected, diseased fruits and branches from the plants and the field (including plant debris) to avoid creating breeding grounds for damaging insects or insects that transmit diseases, or the build-up of inoculum for next season's crop;
- periodic virus screening of material using plant diagnostic kits such as enzyme-linked immune-sorbent assay (ELISA) and DNA-based reverse transcriptase PCR (RT-PCR);
- cleaning any infected clonal materials by thermotherapy and/or tissue culture;

[34] Standard 5.4.3.

[35] Standard 5.4.1.

- keeping insect and pathogen populations under control to avoid major insect and disease infestations; and
- utilizing integrated pest management (IPM) that includes the use of biological control measures, where possible, supplemented with mechanical control and pesticide application as indicated.

✔ **All accessions are regularly monitored for damage by insects, birds and mammals and for any possible vandalism.**

✔ **All field management data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
Data to consider include cultural practices (spacing, weeding, irrigation, fertilizer, pesticide application, etc.), presence of disease or pests, and plant removal (dying or dead plants). Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

Figure 6. Summary diagram of the workflow and activities for field management

6. Regeneration and propagation

Propagation in screenhouse, CATIE Costa Rica

The genebank is recommended to have a documented policy and/or procedure, as applicable, for regeneration and propagation of germplasm, including step-by-step instructions for the review process, pollination control, identity verification, propagation methodologies and documentation.[36]

✔ **The field collection is regularly monitored for dying or dead plants within an accession.**

A plant may lose vigour or die from different climatic, edaphic and/or biotic factors. It is important to set viability thresholds for accessions maintained in the field genebank.[37] Regeneration is carried out for any accessions that fall below these thresholds. For maximum efficiency of a field collection plot, every dead plant should be replaced.[38]

The genebank information management system ideally includes automated tools for checking inventory and plant health, and flagging accessions requiring regeneration and propagation. It is also important to take practical considerations into account in order to avoid planting an overwhelming number of accessions.

✔ **The timing of regeneration is planned to coincide with the normal planting season of the crop.**

Regeneration, like field establishment, will be species- and possibly site-specific. It is important to utilize appropriate practices to ensure success, for example:

- planning the raising of rootstocks in such a way as to ensure that they reach

[36] See Figure 7 at the end of this section for a summary diagram of the workflow and activities for regeneration and propagation.

[37] See section on establishment of field collections for general guidelines.

[38] Standard 5.5.1.

appropriate size for grafting at the best season for propagation and when scions become available;
- initiating propagation when propagules start to sprout or mother plants start to die; and
- having a clear understanding of established planting times for species/species groups (e.g. FAO, 2021d).[39]

✔ **Whenever possible, plants are propagated vegetatively to ensure that each offspring is a genetic duplicate of the parent plant.**

True-to-type plant material should ideally be used for propagation to ensure the genetic integrity of the accession.[40] It is not recommended to use seeds for propagation in a field collection unless the population is represented by a sufficiently large number of plants. Practices to consider include:
- choosing rooting, budding and grafting options for vegetative propagation (for examples of propagation techniques, see Roots of Peace, 2007);
- storing propagation materials in special facilities (e.g. greenhouses/screenhouses, *in vitro* or freezer) to ensure their health;
- opting for ratooning, i.e. allowing suckers to develop and produce the next crop in collections of edible aroids, which will extend the time between regenerations;[41] and
- periodically monitoring trueness to type of long-lived shrubs and trees.

✔ **In the case of annual crops, storage facilities are available and easily accessible for vegetative propagules that are harvested annually and kept in storage until the next planting season.**

For annual species such as many alliums, their propagules must be harvested and replanted each season. Each replanting is considered a regeneration cycle. It is therefore necessary to have designated storage facilities that are as impermeable as possible to insects, and rodents and other small mammals. The following practices are suggested:
- It is essential that storage propagules are free of damage caused by insects and nematodes and any other visible symptoms of diseases before storage. Pre-treatment is therefore necessary to disinfect the storage propagules after harvest and before storage.
- Vegetative propagules of several tuber crops, including potato, sweet potato, yam and cassava, can be conserved under cold conditions of 4–20 °C for several months between one harvest and the next planting season.
- For those species with ambient storage of propagules, propagules are selected for storage in mesh sacks, or open boxes made of wood or plastic to allow air circulation.

[39] Note: FAO has published crop calendars for Latin America and Africa that are helpful in this regard.

[40] Standard 5.5.2.

[41] Note: This practice is only recommended when the collection is free from major root and leaf diseases.

- Species stored as stems can be stored in bundles or in polythene bags with the cut ends covered with wax to prevent excessive drying during storage.
- Stored propagules should be identified with labels both inside and outside the storage container.
- It is recommended to monitor the material weekly for signs of rotting, insect damage or rodent damage.

✔ **Appropriate field management and cultural practices are applied.[42]**

✔ **Accessions are verified for their trueness-to-type in the field.**
True-to-type plant material should ideally have been used for initial propagation to ensure the genetic integrity of the accession.[43] The following practices should be considered:
- using reference accessions in the same field to facilitate identification;
- using herbarium specimens and possibly digital high-quality voucher images to guide true-to-type identification, including taxonomic identification and verification, if needed;
- observing the homogeneity/heterogeneity of the accession; and
- using molecular marker analysis, if feasible.

✔ **All field management data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.[44]**
Data to consider include the site where regeneration/rejuvenation is carried out, type of propagation (cuttings, tubers, corms, bulbs, seeds), planting date, survival rate of the propagated material, management practices employed, method of planting, field conditions, number of plants established for each accession and harvest date. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

[42] See section on establishment of field collections

[43] Standard 5.5.2.

[44] Standard 5.5.3.

Figure 7. Summary diagram of the workflow and activities for regeneration and propagation

7. Characterization

Taro germplasm, Plant Genetic Resources Research Institute Ghana

The genebank should have a documented policy and/or procedure, as applicable, for characterization of germplasm, including step-by-step instructions describing sampling techniques, growth cycle stages during which characterization data are obtained, descriptors used (taxonomic, morphological, phenotypic, biochemical, nutritional, physiological and molecular) and the manner in which the data are collected and validated.[45]

✔ **Characterization data are obtained for as many accessions as possible and as soon as possible.**
Ideally, all accessions should be characterized.[46] The first opportunity for characterization is during germplasm collection. For all species, it is important to characterize a representative number of plants per accession.[47] The sooner the information is available, the more likely it is that the accession will be used. It is essential that staff be well trained in data recording and field work.

✔ **Characterization of perennial field collections is carried out at maturity.**
Phenotypic characterization of the perennial field collections is much easier to perform as the plants are readily and permanently available in the field. The scoring of traits in the field collection can be done at the appropriate time, and repeated over the years, if necessary.

[45] See Figure 8 at the end of this section for a summary diagram of the workflow and activities for characterization.

[46] Standard 5.6.1.

[47] Standard 5.6.2.

✔ **Characterization of annual species is carried out during regeneration.**
Unlike perennial species, annual species, such as alliums, are often regenerated every year. Best practices to consider include:

- using an augmented design, possibly replicated, with carefully chosen check (control) accessions or varieties, as they facilitate the generation of reliable characterization data (IPGRI, 2001);[48]
- creating both hard and electronic copies of field maps developed before planting; and
- clearly labelling plots (preferably with barcodes).

It is advisable to characterize as many accessions as practically possible at the same time in order to increase efficiency.

✔ **Germplasm is characterized for a set of highly heritable morphological traits, and species-specific characterization procedures are based upon standardized and calibrated measuring formats and categories, following internationally agreed descriptor lists as much as possible.[49]**
The use of standardized crop descriptor lists and calibrated and standardized measuring formats enables the comparison of data across institutions and countries.[50] A wide range of crop descriptor lists has been developed, for example by Bioversity International (2018), the International Union for the Protection of New Varieties of Plants (UPOV, 2011), and the National Plant Germplasm System (NPGS) of the United States of America (USDA-ARS, 2021). If there are no existing descriptor lists for a species, it is recommended to use Bioversity International's *Guidelines for Developing Crop Descriptor Lists* (Bioversity International, 2007). It may be helpful to consider:

- using reference accessions in the same field to facilitate scoring;
- using herbarium specimens and possibly digital high-quality voucher images to guide true-to-type identification, including taxonomic identification and verification, if needed;
- observing and documenting the homogeneity/heterogeneity of the accession; and
- taking measurements at the plant level rather than at the plot level for species with high levels of variability in order to capture information about the variability between plants of the same accession.

[48] See section 6.4.

[49] Standard 5.6.3.

[50] Standard 5.6.4.

✔ **Molecular marker technologies and genomic tools for characterization are utilized if resources are available, complementing phenotypic characterization.**

Molecular markers help ensure the identity of plants and to identify mislabelled plants and duplications.[51] They are also highly useful in detecting genetic diversity and parentages within and among accessions. Molecular markers are stable and detectable in all tissues. Molecular marker technologies include DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.[52] Molecular characterization may be outsourced to specialized laboratories.

✔ **All characterization data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**

Data to consider include: planting and harvest dates; cultural practices used (spacing, weeding, irrigation, fertilizer, pesticide application, etc.) and dates when implemented; check (control) accessions or varieties used (for annual species); descriptors measured, results, dates recorded and staff responsible; and laboratory techniques (molecular, etc.), dates carried out and responsible staff. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

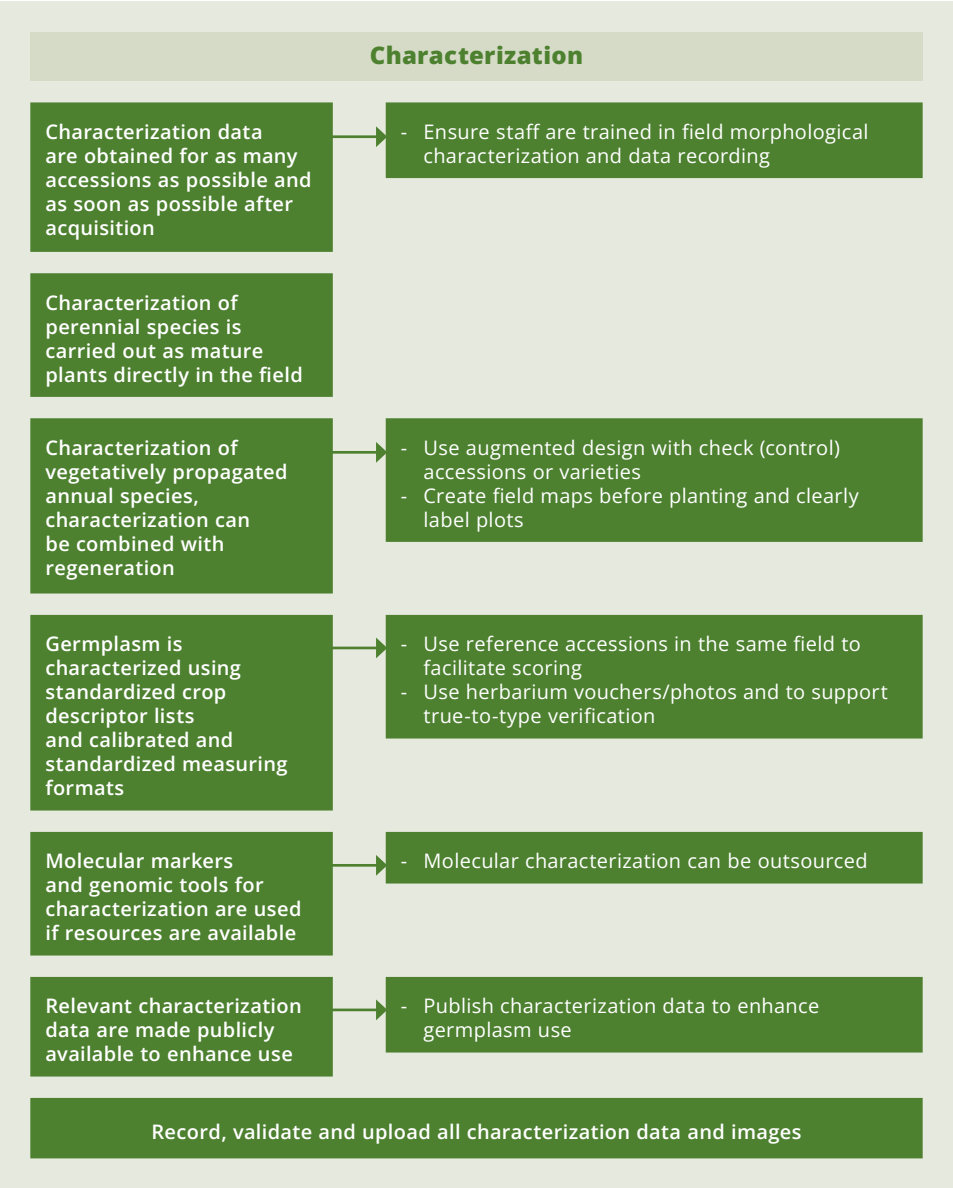
✔ **Relevant characterization data are made publicly available.**

Having data publicly available to potential germplasm users at institute, country, regional and global levels will serve to enhance germplasm use (see documentation section). The publishing of characterization data is therefore highly recommended.

[51] Standard 5.6.3.

[52] A number of resources on the various molecular marker technologies available are available online and in print. Please see further information/reading section.

Figure 8. Summary diagram of the workflow and activities for characterization



8. Evaluation

Musa Germplasm Collection, Uganda

The genebank is recommended to have documented policies and/or procedures, as applicable, for the evaluation of germplasm, including step-by-step instructions describing sampling methodology, replicated multi-location, multiyear designs, growth cycle stages during which evaluation data are obtained, data collected (agronomic performance, biotic resistance, abiotic tolerance and nutritional), and the manner in which the data are analysed and validated.[53] The methods/protocols, formats and measurements for evaluation should be properly documented, with citations.

✔ **Evaluation data are obtained for as many accessions as practically possible, through laboratory, greenhouse/screenhouse and/or field trials, as may be applicable.**

Ideally, all accessions should be evaluated to maximize their utility. In reality, genebanks are usually only able to evaluate subsets of their germplasm. It is therefore helpful to collaborate with national or international research organizations, with field stations in different agroecological environments, or with members of national or regional genetic resources networks. If germplasm is shared for evaluation purposes, it is recommended that a request be made for data to be sent back for inclusion in the genebank information management system.

✔ **Experimental designs with replicates are used and evaluations conducted in different environments and/or over multiple years, when feasible.[54]**

Traits measured during evaluation, such as yield and plant height, are mostly inherited through a large number of genes and therefore quantitative and subject to considerable environmental interaction. Consequently, they are more difficult to measure. Because of the strong genotype by environment (G x E) interactions,

[53] See Figure 9 at the end of this section for a summary diagram of the workflow and activities for evaluation.

[54] Standard 5.7.3.

traits such as yield (and its components) are site-specific. Best practices to consider include:

- defining and identifying check (control) accessions or varieties to be included in the statistical design and used over time, as they facilitate comparisons of data collected across locations and years;
- working with plant breeders and other specialists (for example: plant pathologists, including virologists, entomologists and mycologists; chemists; molecular biologists; and statisticians) to agree on the traits to be evaluated, the accessions to be tested, and the experimental designs to be implemented;
- using appropriate screening protocols to make sure that internationally validated protocols are respected;
- creating both hard and electronic copies of field or greenhouse/screenhouse maps developed before planting; and
- clearly labelling plots or greenhouse/screenhouse pots (preferably with barcodes).

✔ **Evaluation data are presented using appropriate methods.**
The use of standardized crop descriptor lists and calibrated and standardized measuring formats enable the comparison of data across institutions and countries (see characterization section). Data are either presented as discrete values (e.g. scores for severity of disease symptoms or symptoms of abiotic stresses) or as continuous values (e.g. length, height, weight) based on measurements.

✔ **Use molecular markers and genomic tools if resources are available.**
The use of molecular markers in strong linkage with an agronomic trait provides a fast and relatively inexpensive screening methodology in the evaluation of germplasm. They are also highly useful in detecting genetic diversity and parentages within and among accessions. Molecular markers are stable and detectable in all tissues. Molecular marker technologies include DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.[55] If desired, work with molecular breeders to identify marker–trait associations.

✔ **All evaluation data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.[56]**
Data to consider include: location; planting and harvest dates; cultural practices used (spacing, weeding, irrigation, fertilizer, pesticide application, etc.) and dates when implemented; number of replications, check (control) accessions or varieties used; descriptor measured, results, dates recorded and staff responsible; laboratory techniques used (molecular, etc.), dates carried out and staff responsible. Consider the use of electronic devices to avoid transcription errors

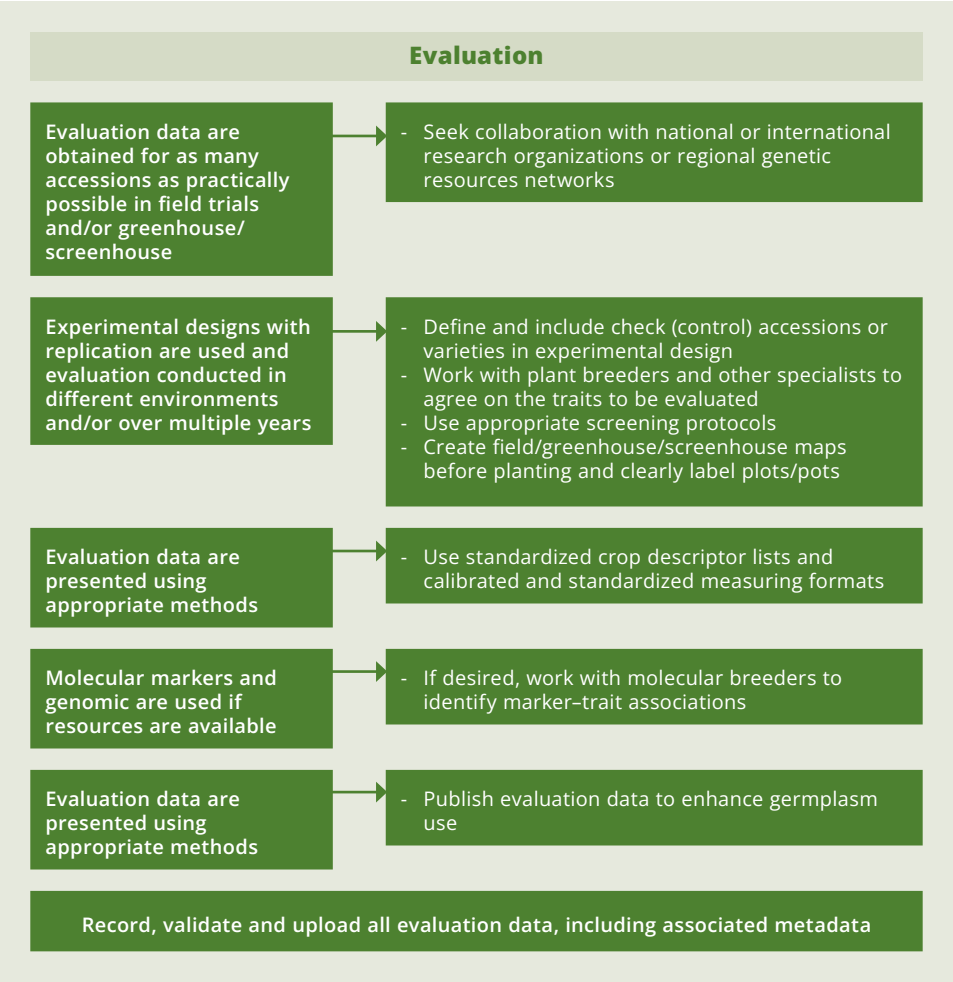
[55] A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.

[56] Standard 5.7.2.

and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

✔ **Relevant evaluation data are made publicly available.**
Making selected data publicly available to potential germplasm users at genebank, country, regional and global levels will enhance its use (see documentation section). The publishing of evaluation data will also promote the use of the germplasm collection, especially by plant breeders.

Figure 9. Summary diagram of the workflow and activities for evaluation



9. Documentation

Genebank documentation, Australian Pastures Genebank

The genebank is recommended have a documented policy and/or procedure, as applicable, for managing genebank data and information, including data-sharing guidelines.[57]

✔ **A genebank information management system is developed specifically for the genebank or one of the several systems available is used/adapted.**
The genebank information system is ideally designed to manage all the data and information generated relating to all aspects of the conservation and use of the germplasm stored in the field genebank, including passport, field-establishment and management, regeneration, characterization, evaluation and distribution data and metadata.[58] Built-in automated tools for checking inventory and plant health, and flagging accessions requiring regeneration should be available.

GRIN-Global has been developed by USDA-ARS, the Global Crop Diversity Trust and Bioversity International to enable genebanks to store and manage information associated with plant genetic resources, and is freely available (GRIN-Global, 2021). Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS) (AVRDC, 2021), the German Genebank Information System (GBIS) (GBIS/I, 2021) and Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa) (Embrapa, 2021).

[57] See Figure 10 at the end of this section for a summary diagram of the workflow and activities for documentation.

[58] Standards 5.8.1 and 5.8.2.

✔ **International data standards are adopted to provide consistency in data shared among different information systems and programmes.**
Recording the passport data of accessions using the FAO/Bioversity Multi-Crop Passport Descriptors (Alercia, Diulgheroff and Mackay, 2015) and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation[59] facilitate data exchange and comparison of accessions across different countries and institutions. Passport data are ideally available for all accessions in the genebank collection.[60]

A unique and permanent accession number is a key element of proper documentation and identification. The voluntary use of Digital Object Identifiers (DOIs) (Alercia, Diulgheroff and Mackay, 2015; FAO, 2021a) is an additional option for information sharing across different information systems and different communities but cannot replace the assignment of the genebank's unique and permanent accession number.

✔ **All data and information relating to all aspects of the conservation and use of germplasm, including images and metadata, are validated and uploaded to the genebank information management system.[61]**
Having trained staff responsible for data recording and data entry in close collaboration with documentation officers and germplasm collection curators supports quality control. It would be useful to have staff members that are assigned specific responsibility for managing the genebank information management system, including keeping data up to date at all times. Validation of data by genebank curators and documentation officers before being uploaded into the genebank information management system is recommended.

✔ **Mobile devices are used to capture data, if possible.**
The use of barcoding facilitates all aspects of genebank management, especially documentation.

✔ **Data recorded on paper are digitalized and measures are put in place to check hand-written and electronic data entries for transcription errors.**

✔ **Data are publicly available in a search-query database, if possible.**
Publishing data on the genebank holdings increases opportunities for use of germplasm and therefore gives value and prestige to genebanks. It may not be possible for all genebanks to maintain a web portal for external access to collection information. An option is to provide information through Genesys, an international global portal managed by the Global Crop Diversity Trust (Crop

[59] See characterization and evaluation sections.

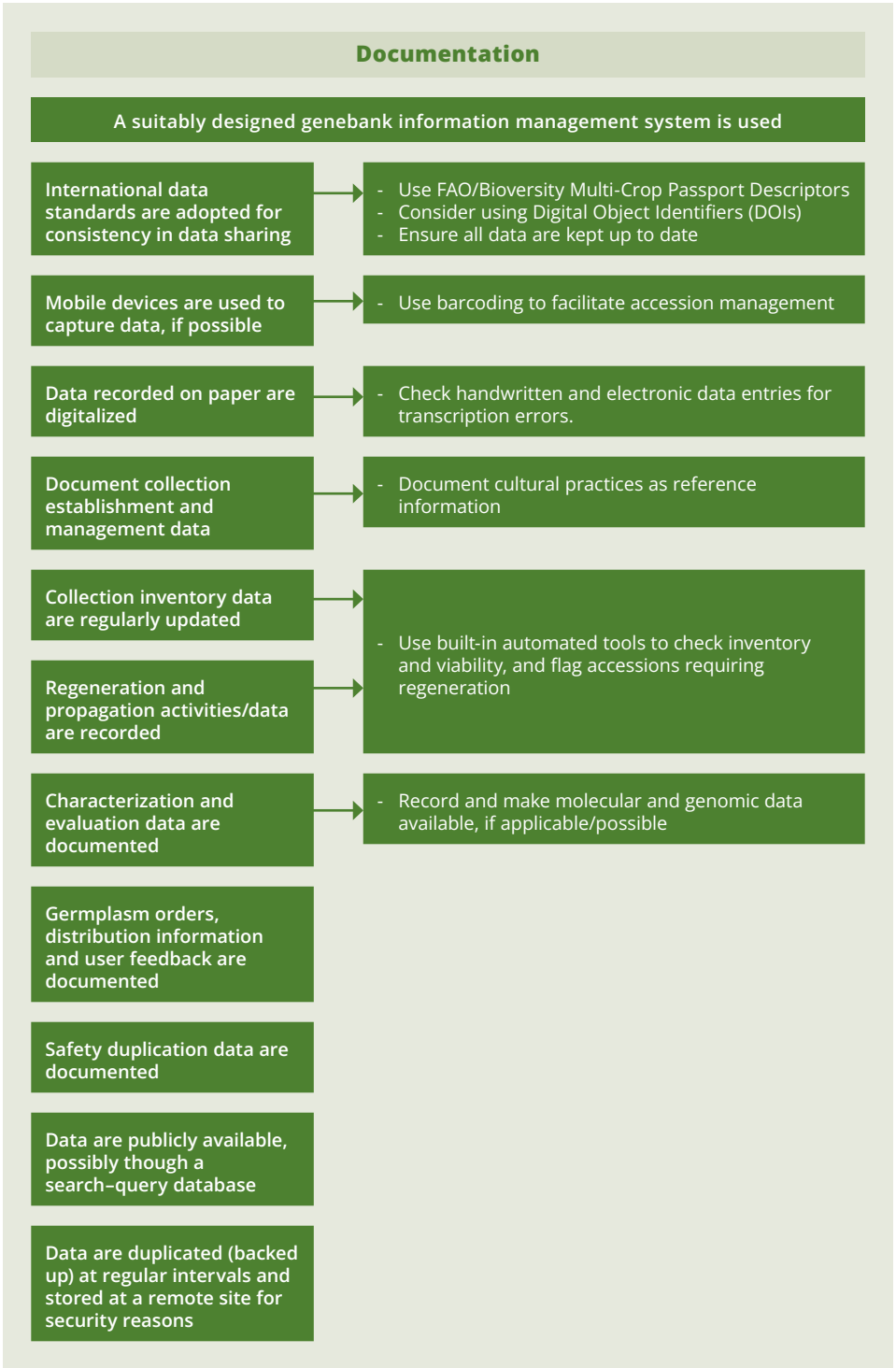
[60] Standard 5.8.1.

[61] Standard 5.8.3.

Trust, 2021). Genesys allows accession data from genebanks around the world to be shared, and facilitates the ordering of germplasm. It includes accession-level passport, characterization and evaluation data as well as environmental information associated with accession collecting sites. Another option for making the passport data of genebank accessions publicly accessible is provided by the FAO World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) (FAO, 2021e). By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals (United Nations, 2021), WIEWS stores and publishes accession-level passport data for the largest global inventory of *ex situ* collections (FAO, 2021f).

✔ **Data are duplicated (backed-up) at regular intervals and stored at a remote site to guard against loss from fire, computer failure, data breach, etc.**

Figure 10. Summary diagram of the workflow and activities for documentation



10. Distribution

Sweetpotato, Tanzania Agricultural Research Institute

The genebank is recommended to have a documented policy and/or procedure, as applicable, for the distribution of germplasm, including the review process for checking for fulfilment of legal, phytosanitary and other regulations and requirements, and step-by-step instructions for consignment preparation, post-consignment follow-up and reporting to the Secretariat of the Treaty or a National Focal Point or other designated as authority, as necessary.[62]

✔ **The genebank complies with national, regional and international regulations and agreements.[63]**

The process of germplasm distribution is governed by national and international regulations. The genebank should communicate with the appropriate designated authorities when there are questions regarding germplasm distribution. The following information should assist in ensuring compliance.

- The genebank should communicate with the Secretary of the Treaty or a National Focal Point or other designated authority if other countries are involved in germplasm distribution.
- If the genebank's country is a signatory to the Treaty and germplasm of crops or species listed under Annex 1 of the Treaty (FAO, 1995) is being distributed for the established intended uses (i.e. research, breeding and training for food and agriculture), it is necessary to use a SMTA (FAO, 2021b; c).
- If the genebank's country is not a Contracting Party to the Treaty or if the germplasm is not covered under Annex 1, it is recommended that an agreement be reached with the recipient on the terms and conditions of germplasm distribution – covering, for example, the use and onward sharing of

[62] See Figure 11 at the end of this section for a summary diagram of the workflow and activities for distribution of germplasm.

[63] Standard 5.9.1.

the material or its derivatives, data reporting, etc. An MTA is usually used (e.g. AVRDC, 2012), though an SMTA could also be used.

✔ **A policy is in place for the number of propagules to distribute for any given accession.**
For accessions with too few propagules at the time of request, and in the absence of a suitable alternative accession, samples are supplied after regeneration, based on a renewed request. For some species and for some uses, a smaller number of samples is sufficient.

✔ **Required documentation is requested and obtained.**
Import permit regulations, which specify phytosanitary and any other import requirements, including packaging requirements, must be requested from the relevant national authority of the receiving country. Documents often required by the recipient country include a phytosanitary certificate, additional declarations, a certificate of donation, a certificate of no commercial value and an import permit.

✔ **Vegetative material from field genebanks is subjected to therapy and indexing procedures before it is distributed to germplasm users.**
- Surface decontamination methods are applied that eliminate contaminants from explants excised from field-grown or greenhouse/screenhouse-grown material (*ex vivo*).
  - Examples include sterilizing using bleach solution, hot water treatment and treatment with ozone dissolved in water (see Umber *et al*., 2020).
- Vegetative materials are indexed for, and determined to be free of, known viruses.
  - Routine indexing procedures include enzyme-linked immune-sorbent assay (ELISA), polymerase chain reaction (PCR), reverse transcriptase PCR (RT-PCR) and non-radioactive probe-based nucleic acid spot hybridization (NASH) techniques were developed and validated for routine testing (see Selvarajan *et al*., 2009).

✔ **Arrangements are made with competent authorities or agents (i.e. the country's National Plant Protection Organization) to inspect or test the material in order to ensure compliance with the regulations of the importing country and to issue the relevant phytosanitary certificate.**

✔ **The length of time between receipt of a request for samples and their dispatch is kept to a minimum.**

✔ **Samples are labelled carefully and are not mixed during handling.**
Correctly labelled samples, preferably with computer-produced labels to reduce transcription errors, should be placed both outside and inside each packet to ensure that the material is properly identified.

- ✔ **The choice of packaging material and transport allows for safe and timely delivery.**
  Ensure that the material reaches the destination genebank in good condition, bearing in mind the time needed for document processing, duration of shipment, transit time and transit conditions (high temperatures and/or humidity in tropical countries). The use of packing and shipping guidelines/recommendations similar to those utilized for acquisition is recommended for cuttings (see acquisition section). Alternatively, if distributing *in vitro* plantlets, sterile transparent watertight sealed plastic vials should be used, and packed firmly but not too tightly in a box or carton, with the addition of crumpled paper or polystyrene material to protect against shocks.

- ✔ **All required documentation is included inside the shipment (for the recipient) and attached to the outside of the container for the customs officials in order to guarantee smooth processing during transit and at the border of the destination country.**[64]
  It is recommended that relevant information be sent with the shipment,[65] including data on accessions (including an itemized list with accession identification, number and/or weights of samples, and key passport data), and import permit, phytosanitary certificate or customs declaration, if appropriate.

- ✔ **The delivery of the germplasm and its condition on arrival at its destination is checked by following up with the recipient.**
  It is recommended to track the shipment and follow up with the recipient on the status and performance of the distributed germplasm.

- ✔ **All distribution data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
  Data to consider include: requester's name and address, purpose of request and request date; samples requested, samples sent and number of propagules per accession; virus indexing method and/or surface treatment; reference to phytosanitary certificate and SMTA or MTA; and shipping log and user feedback. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

64 Standard 5.9.2.

65 Standard 5.9.3.

Figure 11. Summary diagram of the workflow and activities for distribution of germplasm

11. Safety duplication

International Cocoa Genebank, Trinidad

The genebank is recommended to have a documented policy and/or procedure, as applicable, for the safety duplication of germplasm, including the review process for checking for fulfilment of legal, phytosanitary and other regulations and requirements, and step-by-step instructions for consignment preparation, post-consignment follow-up and shipment schedules.[66,67]

✔ **A safety duplicate sample for every original accession is stored in a distant area, under appropriate conditions and utilizing best practices, and/or backed up by an alternative conservation method/strategy.[68]**
Safety duplicates are deposited at a different location well away from the main collection and usually in another country. The safety duplicate location is chosen to minimize possible risks and provide the best possible conditions, taking into account the need for adequate facilities, staff and financial resources. It should be in a sociopolitically and geophysically stable location. The genebank/institute hosting the safety duplicates should have adequate capability to provide appropriate field and/or *in vitro* conditions for the duplicated accessions. Alternatively, samples can be cryopreserved at the duplicating centre.[69] The selection of, and clear agreement with, the chosen holder of the safety duplicate are critical.

66 Duplicated material includes plants to be managed in the field, plantlets maintained *in vitro* or meristematic tissues under cryopreservation.

67 See Figure 12 at the end of this section for a summary diagram of the workflow and activities for safety duplication of germplasm.

68 Standard 5.10.4.

69 See Genebank Standards (Chapter 6).

✔ **A legal agreement setting out the responsibilities of the depositing and the recipient genebank, and the terms and conditions under which material is maintained and managed, should be in place.**
If the holding genebank does not already have an agreement with another genebank to duplicate the original accessions, consideration should be given to where best they could be duplicated, which will depend on the chosen method of safety duplication.

✔ **The genebank complies with legal, phytosanitary and other regulations and requirements, and each safety duplicate sample is accompanied by relevant associated information.**
Discussions should take place with the host genebank early in the planning process on the required documentation (both for the genebank and the host country) and the applicable customs and quarantine procedures. This will help to ensure timely movement of the germplasm.

✔ **The safety duplicate is of high quality and consists of a sufficient quantity of material.**
It is the depositor's responsibility to ensure that the deposited material is of high quality. Best practices include:
- duplicating clean and healthy material; and
- ensuring that safety-duplicated samples are large enough to avoid risk of loss.[70]

✔ **Samples are labelled carefully and are not mixed during handling.**
It is important to ensure that samples are correctly labelled, preferably with computer-produced labels to reduce transcription errors in names and numbers.

✔ **The choice of packaging material and transport allows for safe and timely delivery.**
Ensure that the material reaches the destination genebank in good condition, bearing in mind the time needed for document processing, duration of shipment, transit time and transit conditions (high temperatures and/or humidity in tropical countries). The use of packing and shipping guidelines/recommendations similar to those utilized for distribution is recommended (see distribution section).

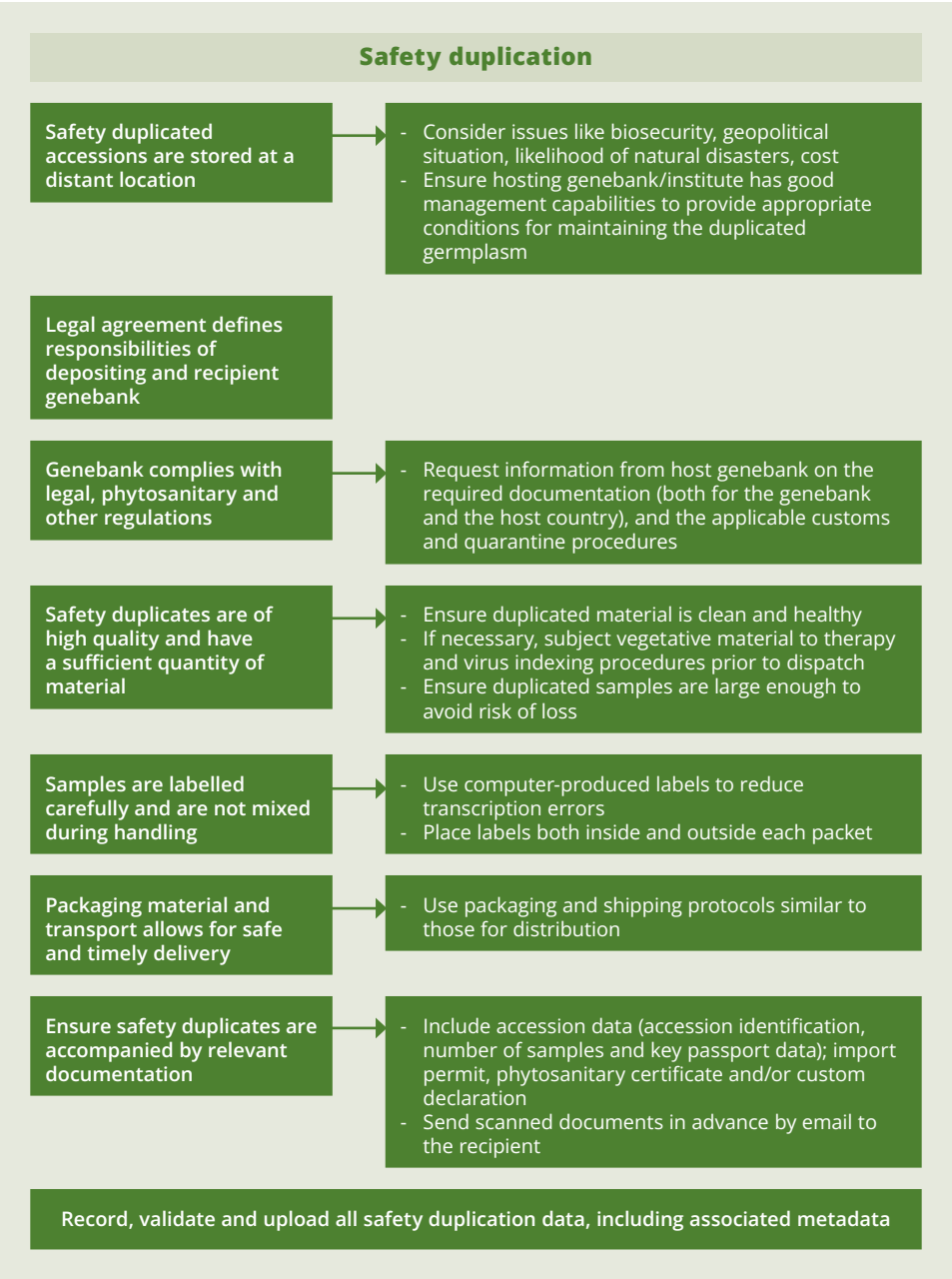
✔ **Each safety duplicate sample is accompanied by relevant associated information.**
It is recommended that relevant information be sent with the shipment, including an itemized list with accession identification, key passport data, total quantity of propagules (by weight or number), type of container, etc. Consider scanning documents and sending them by email, or sending hard copies by mail, prior to the dispatch of the germplasm.

[70] It is recommended to duplicate at least 2–3 plants for vegetatively propagated woody or herbaceous perennial crops and in the range of 4–10 for annual crops.

- ✔ **All safety duplication data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**
  Data to consider include: location of the safety-duplicated accessions; samples sent and number of replicates per accession and shipping log; and reference to legal agreement, phytosanitary certificate, etc. Consider the use of electronic devices to avoid transcription errors and for ease of uploading into the genebank information management system. Otherwise, the use of indelible ink (or pencil) and clear, legible writing is required when recording data. The use of barcode labels and barcode readers facilitates accession management and minimizes human error.

- ✔ **The genebank information management system is regularly reviewed and updated to ensure that any new material not duplicated in the recipient genebank is identified and prepared for safety duplication, as appropriate.**

Figure 12. Summary diagram of the workflow and activities for safety duplication of germplasm



12. Personnel and security

Safe application of pesticides, Egypt

Personnel:

It is recommended that the genebank have a strategy in place for personnel, including a succession plan; a corresponding budget must be allocated and reviewed regularly.[71]

- ✔ **The genebank has a human-resources plan with appropriate annual budget allocation, and staff have the critical knowledge, skills, experience and qualifications needed to implement all genebank tasks effectively and efficiently.** Successful genebank management requires a minimum of well-trained staff with clearly defined responsibilities for accession management.[72] The following practices should be considered:
  - ensuring that the genebank manager and those staff carrying out specific tasks regularly review and update SOPs, as applicable;
  - ensuring that curators and technical support staff have knowledge and skills in agriculture, horticulture and taxonomy of cultivated plants and their wild relatives;
  - having access to disciplinary and technical specialists in a range of subject areas, such as taxonomy, physiology, phytopathology, breeding and population genetics;
  - holding regular on-the-job training sessions and, if possible, ensuring that staff can attend training opportunities at regular intervals to keep up to date with recent developments;

[71] See Figure 13 at the end of this section for a summary diagram of the workflow and activities for personnel and security.

[72] Standard 5.10.3.

- rotating tasks to make work as varied as possible and involving all staff (where possible) in meetings and discussions; and
- retaining competent staff by providing recognition and rewards for excellent performance.

✔ **Risks associated with staffing are included in the risk identification, analysis and management.**
Secure conservation depends on accurate assessment and appropriate management of risks (see Annex). Therefore, all genebanks should establish and implement risk management strategies that address the physical and biological risks in the everyday environment to which the staff, collections and related information are exposed.

Security:

A genebank is recommended to have a documented risk management strategy in place that includes measures for dealing with power cuts, fire, flooding, earthquakes, war and civil strife.[73] This strategy and an accompanying action plan should be regularly reviewed and updated to take changing circumstances and new technologies into account.

✔ **A risk management strategy is in place.**
A risk management strategy has the following components (SGRP-CGRFA, 2010):
- *Communication and consultation*: ensure that all those who will be involved in implementing a risk management system are oriented in the concepts, methodology, terminology, documentation requirements and decision-making processes of the system.
- *Establishing the context*: consider the objectives/activities/tasks of the genebank, the environment in which the activities operate, and the stakeholders.
- *Risk identification*: carry out an inventory of relevant risks to the genebank operations.
- *Risk analysis*: assess the potential impact (or consequence) of the identified risks and their likelihood (probability).
- *Risk evaluation*: determine the level of risk that is acceptable.
- *Risk treatment*: identify actions that need to be undertaken in order to deal with those risks for which the current total risk rating is considered unacceptable, giving top priority to the highest assessed residual risks.
- *Monitoring and review*: analyse the risk management system and assess whether changes to the system are needed. Responsibilities for monitoring and review should be clearly defined and documented.

[73] Standard 5.10.1

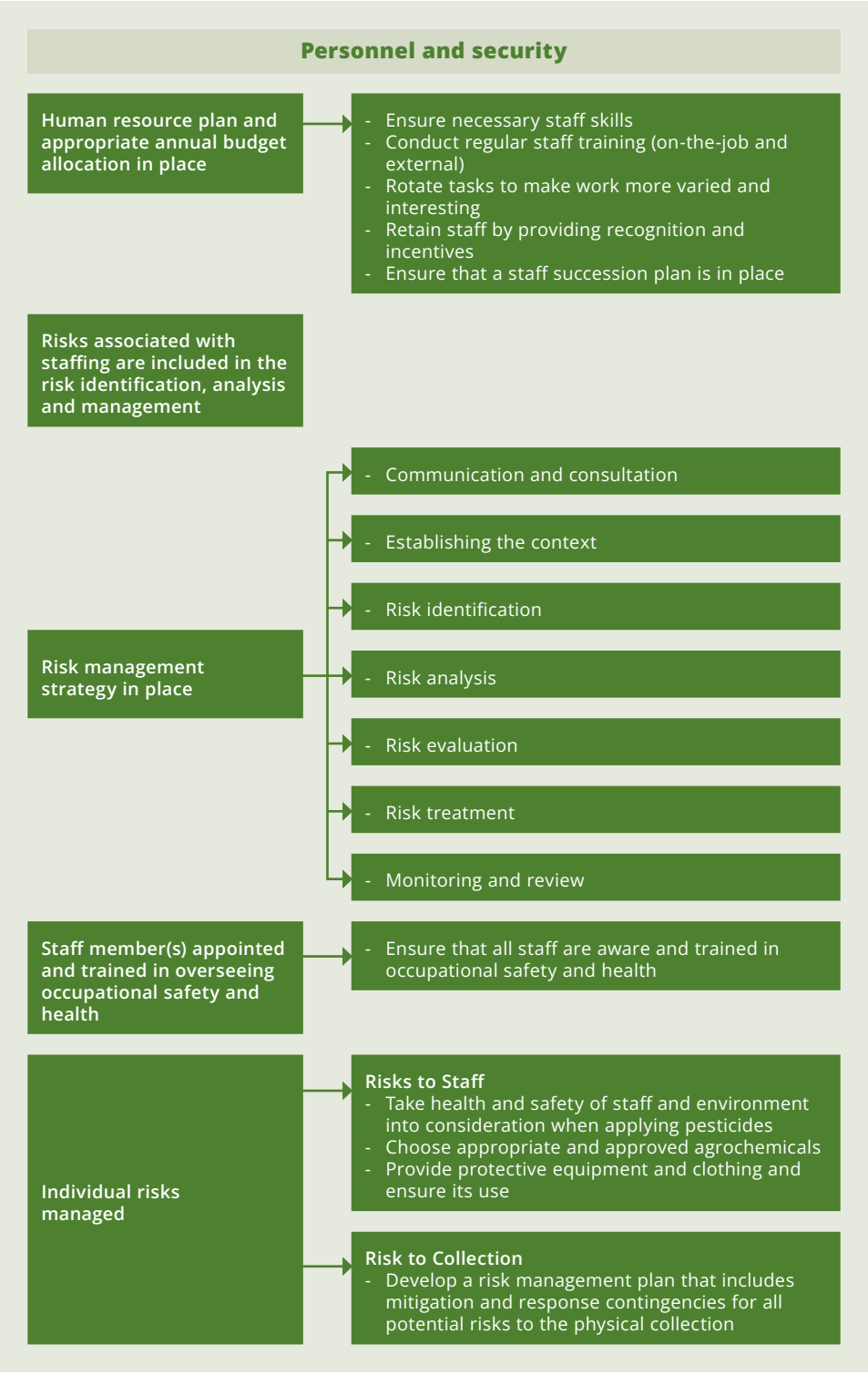
✔ **A staff member with responsibility for occupational safety and health (OSH) in the genebank is appointed and receives training in OSH.**
OSH deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards.[74] Most countries will have an OSH policy. The International Labour Organization (ILO, 2021) provides country profiles on OSH.

✔ **All staff are aware of OSH requirements and are kept up to date regarding any changes.**
It is recommended that all genebank staff be made aware of the details of the risk management strategy and have a clear understanding of responsibilities for implementing and monitoring the strategy and action plan. Best practices to consider include:

- ensuring that OSH rules are visible in the more risk-prone areas of the genebank;
- instructing staff in the correct and safe use of equipment with regular training provided in health and safety in field, greenhouse/screenhouse and laboratory environments;
- choosing appropriate and nationally approved agrochemicals to reduce risk; and
- providing properly functioning protective equipment and clothing, as required by OSH, and ensuring that they are regularly checked and used as expected. The OSH officer is responsible for the upkeep of safety equipment.

[74] Standard 5.10.2.

Figure 13. Summary diagram of the workflow and activities for personnel and security



13. Infrastructure and equipment

Greenhouse facilities, CIAT genebank

This section considers the suggested infrastructure and equipment for a field genebank (Table 2). The infrastructure needs of a field genebank are relatively easy to meet. There is a need for office space to accommodate the curators and field technicians and the documentation officer. A greenhouse/screenhouse for keeping certain accessions that are difficult to maintain in the field under more controlled conditions is often desirable. The greenhouse/screenhouse may also serve for grafting purposes. Shaded nursery facilities where grafted or rooted materials can be grown until they are ready for field transplanting are necessary. Fencing of the field genebank may be necessary in order to protect the plants from invading animals or theft. The facility should adhere to the law and to the requirements of relevant regulatory bodies, and the operating environment and equipment should conform to relevant national and international standards and safety regulations.

References are available for setting up and running field genebanks, and these are included in the Further Information/Reading section. An important rule to remember is that operations and workspace design should be planned so that germplasm and materials do not become contaminated, lost or misplaced. Physical delineation of clean and dirty areas, with samples progressing one-way through increasing levels of cleanliness and security is one way in which contamination and workflow can be controlled.

Table 2: General infrastructure and equipment recommended for a field genebank

Genebank operation/management area
General needs
Office space and supplies; computers, printers and accessories; climate data loggers; mobile devices for electronic data recording and barcode readers; access to scientific and technical literature; internet access
Acquisition
Collecting equipment, including cloth and/or paper bags, moisture-retaining bags/containers for recalcitrant seeds, labels (ideally barcode labels), hand lenses, scissors, tarpaulins, secateurs, packaging materials, herbarium presses
Data collection sheets or mobile devices for electronic data recording, GPS or altimeter
Incinerator, surface decontamination solutions, knives, forceps, scalpels, balance for weighing fruit and seeds, camera for recording samples on arrival
Field establishment and management
Tractor(s) and attachments (ploughs, rotavators, etc.), equipment for pesticide applications (sprayer, motor-driven or hand-held), irrigation equipment/water supply, grafting and pruning tools, support structures (trees, wooden sticks, wires, etc.), netting, etc.
Regeneration and propagation
Greenhouse/screenhouse or field space for growing cuttings, pots, compost, rootstock, rooting media
Characterization and evaluation
Access to field, laboratory or greenhouse/screenhouse areas as required
Field/laboratory/greenhouse/screenhouse equipment and machinery, as necessary, according to species and traits being recorded
Pots and plot stakes and labels (ideally barcoded labels), labelled cloth bags or other appropriate containers
Molecular analysis (RAPD, ISSR, SSR) equipment, if possible
Data sheets or mobile devices for electronic data recording, barcode reader

Table 2 *(Cont.)*

Genebank operation/management area
Documentation
Suitable designed database/genebank information management system aligned to FAO/Bioversity MCPDs and other data standards, e.g. GRIN-Global
Database with built-in automated tools to check inventory and plant health, and flag accessions requiring regeneration and propagation
Data backup/storage
Distribution and safety duplication
Moisture-retaining bags/containers for cuttings or sterile plastic bags for *in vitro* germplasm. Heat-sealable plastic bags and sealing machine, labels (preferably barcode labels), packaging materials
Data sheets or mobile devices for electronic data recording, barcode reader
Security and personnel
Generator(s), fire extinguishing equipment, security cameras, alarm systems, security doors
Protective clothing and protective gear such as dust masks, gloves and footwear

14. References

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15. Further information/reading

The list of references below provides guidance and/or technical background on genebank operations and management. Additional references can be found in the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (FAO, 2014).

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Annex: Risks and associated mitigation

It is important that staff are properly trained and follow documented procedures at all stages of genebank operations. Specific risks to be considered during genebank operations are presented below.

Choice of location of the field genebank

Risk	Risk control/mitigation
Loss of adaptive alleles due to selection pressures	■ Choose a site with agroecological conditions as similar as possible to the environment where the collected plant materials originated ■ Choose a location that minimizes risks from natural and human-made disasters
Inability to expand or maintain the collection over the long term	■ Ensure the site is secure over the long term (minimum of 50 years) based on written, guaranteed or gazetted land tenure ■ Ensure that the site provides sufficient space for future expansion ■ Maintain a safe distance of at least 10 km radius from volcanos and avoid areas that are frequently in the path of hurricanes, typhoons or snow avalanches ■ Avoid areas close to human settlements known to be affected by civil strife

Risk	Risk control/mitigation
Loss if viability/health of collection	■ Select a site suitable for using machinery for mulching and fertilizer and pesticide applications ■ Ensure the site has easy access to a water source for pesticide applications and supplemental irrigation, as required ■ Choose a location where the target crop has not been grown recently in order to avoid heavy infestation of major diseases or pests
Loss of purity due to cross-pollination, in the case of outcrossing species that are used to produce seeds for distribution.	■ Choose a site that minimizes risks of gene flow and contamination from crops and wild populations of the same species, and from related species with which the conserved species can cross-pollinate

Acquisition

Risk	Risk control/mitigation
Diversity of the source population is not adequately represented in the collected sample	■ Develop and follow agreed collecting strategy and methodology that adequately follow genetic sampling guidelines
Taxonomic misidentification	■ Include a taxonomist in the collecting team, and have genebank staff trained in taxonomy ■ Take herbarium vouchers and photos for verification by experts ■ Ensure that data collection sheets include other descriptors to be recorded during collecting mission
Mislabelling/loss of labels	■ Firmly attach one label to the outside of each collecting bag; place another label inside the collecting bag
Transcription errors	■ Consider the use of mobile devices, ensuring regular data backup and availability of sufficient charged batteries ■ Implement data validation
Loss of viability during collecting missions/transport leading to reduced seed longevity (and earlier regeneration)	■ Ensure timely transfer to controlled conditions ■ Ensure appropriate post-harvest handling according to the maturity of the seeds/the state of vegetative material and the prevailing environmental conditions

Field management

Risk	Risk control/mitigation
Loss of adaptive alleles due to selection pressures	■ Follow appropriate cultural practices for optimum growth and survival
Loss of viability	■ Follow appropriate cultural practices for optimum growth and survival ■ Carry out disease prevention and control measures in timely manner ■ Remove any infected, diseased fruits and branches
Loss of genetic integrity	■ Rogue out any volunteer seedlings ■ Monitor collections regularly ■ Verify accession labels periodically with the field map ■ Verify accession identify using morphological and molecular markers periodically, when possible
Accession in field falls below viability/quantity thresholds	■ Ensure that the documentation system includes automated tools for monitoring seed-lot viability and inventory and flagging accessions requiring regeneration

Regeneration and propagation

Risk	Risk control/mitigation
Loss of adaptive alleles due to selection pressures	■ Follow appropriate cultural practices ■ Regenerate at sites with a similar climate to that of the collection site where the material originated ■ Outsource regeneration if necessary
Loss of purity due to cross-pollination from other accessions of the same species (of outcrossing species that are used to produce seeds for distribution)	■ Follow recommended crop-specific isolation distances or use isolation cages, bagging or other pollination-control measures
Poor levels of pollination (for outcrossing species that are used to produce seeds for distribution)	■ Use pollination cages to enclose insect pollinators. ■ Ensure adequate availability of insect pollinators ■ Hand-pollinate as required/where possible
Misidentification of accession	■ Check plot and bag labels prior to planting and harvesting; use barcode labels

Characterization and evaluation

Risk	Risk control/mitigation
Poorly recorded, unreliable data	■ Train staff well ■ Use appropriate cultural practices ■ Use mobile devices to record field data ■ Ensure data validation by curator and/or documentation officer
Misidentification of accession	■ Use check accessions/varieties (for vegetatively propagated annuals) ■ Check plot labels while collecting data ■ Check plot and bag labels prior to sowing and harvesting

Distribution and safety duplication

Risk	Risk control/mitigation
Mixing/mislabelling of samples	■ Pack carefully to avoid mixing ■ Place labels inside and outside the package ■ Use computer-generated barcode labels to minimize errors
Viability loss due to delayed or damaged shipments	■ Pack carefully ■ Ensure samples are dispatched promptly, and use the fastest and safest way of sending.

FAO has developed the *Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation in field genebanks* to be used as a companion volume to the *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. The action steps of the genebank workflow are presented in a sequential manner and provide guidance on the complex steps and decisions required when operating a field genebank. The accompanying summary charts for the respective action steps underscore the intended use of this practical guide as a handbook for routine genebank operations for the conservation of plants in the field. While this practical guide is particularly useful for genebank technicians for their day-to-day activities, it may also be used as a basis for the development of standard operating procedures and quality management systems. Genebank managers will also find it useful for conducting training exercises.

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