COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 12.2 of the Provisional Agenda

Eighteenth Regular Session

27 September – 1 October 2021

DRAFT PRACTICAL GUIDES FOR THE APPLICATION OF THE GENE BANK STANDARDS FOR PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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Documents can be consulted at www.fao.org

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I. INTRODUCTION

1. The Commission on Genetic Resources for Food and Agriculture (Commission) at its Fourteenth Regular Session endorsed the Genebank Standards for Plant Genetic Resources for Food and Agriculture\(^1\) (Genebank Standards), which provide international standards for the ex situ conservation of plant genetic resources for food and agriculture (PGRFA) in seed banks, field genebanks, in vitro cultures and under cryopreservation. The Genebank Standards constitute an important tool for implementing both the International Treaty on Plant Genetic Resources for Food and Agriculture\(^2\) (Treaty) and the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture\(^3\) (Second GPA).

2. The Commission, at its Fifteenth Regular Session, requested FAO to propose a mechanism for monitoring the application of the Genebank Standards.\(^4\) As step towards responding to this request and in a bid to obtain feedback on the utility of the Genebank Standards from a wide stakeholder base, FAO undertook a global survey of relevant practitioners at national, regional and international genebanks in 2017. Based on 104 respondents from 56 countries, the Genebank Standards were generally considered a very useful tool for standardizing genebank operations based on validated best practices.\(^5\) However, it was indicated that the stepwise activities of routine genebank operational workflows were not easily evident in the Genebank Standards. To address this identified shortcoming, FAO prepared sequential action steps for genebank operations.\(^6\) These steps were adapted from the Genebank Standards and reflect the current state of the art in genebank operations. Subsequently, FAO, in collaboration with the Global Crop Diversity Trust, organized an expert consultation in 2018 to examine the findings of the survey and to review and revise the draft action steps.\(^7\) The expert opinions were incorporated into the draft action steps.

3. The Commission, at its Seventeenth Regular Session, considered the draft action steps of the workflows for routine genebank operations for the conservation of plant germplasm as orthodox seeds, in field genebanks, and as in vitro cultures, respectively.\(^8\) It requested FAO to prepare practical guides for the use of the Genebank Standards, based on the proposed action steps, for consideration at the next sessions of the Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture (Working Group) and the Commission.\(^9\)

4. In response to this request, FAO prepared three Draft Practical Guides for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture (Draft Practical Guides) for the conservation of, respectively, orthodox seeds at low temperatures, vegetatively propagated plants in field genebanks, and in vitro cultures of meristematic tissues.

5. The Working Group considered the Draft Practical Guides\(^10\) and requested additional time to review them and provide comments.\(^11\) It invited Commission Members and observers to submit written comments to the Secretariat and requested the Secretariat to revise the Draft Practical Guides in the light of the comments received, for endorsement by the Commission at its Eighteenth Regular Session. The

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\(^{4}\) CGRFA-15/15/Report, paragraph 51.

\(^{5}\) CGRFA-17/19/9.2/Inf.5, paragraphs 5-10.

\(^{6}\) CGRFA-17/19/9.2/Inf.5, Annex 1-3.

\(^{7}\) CGRFA-17/19/9.2/Inf.5, paragraphs 11-15.

\(^{8}\) CGRFA-17/19/9.2/Inf.5.

\(^{9}\) CGRFA-17/19/Report, paragraph 65.

\(^{10}\) CGRFA/WG-PGR-10/21/2.2/Inf.1.

\(^{11}\) CGRFA-18/21/12.1.
Draft Practical Guides were revised by FAO in light of the comments received from eight countries and one international organization.12

II. KEY FEATURES OF THE DRAFT PRACTICAL GUIDES FOR THE APPLICATION OF THE GENEBANK STANDARDS

6. The Draft Practical Guides respectively address routine genebank operations for the conservation of orthodox seeds in seed genebanks, conservation of whole plants in field genebanks and conservation of plantlets via in vitro culture. They are underpinned by the underlying principles of all genebank management,13 as outlined in chapter 2 of the Genebank Standards.

7. The purpose of the Draft Practical Guides is to present the information contained in the Genebank Standards in a format that details the actions of the genebank workflow in a sequential manner and thereby facilitate more widespread application of the Genebank Standards. As such, they aim to contribute to an efficient and sustainable system of ex situ conservation. Genebanks may use the activities outlined in these guides as a basis for the development of Standard Operating Procedures and Quality Management Systems for conserving germplasm collections, defining in detail how to carry out each activity.

8. The three Draft Practical Guides are presented in Annexes 1, 2 and 3 to this document and are summarized below.


9. This Draft Practical Guide presents routine operations for the conservation of orthodox seeds (i.e. Chapter 4 of the Genebank Standards).14 The individual sections provide, respectively, detailed information on actions and best practices for acquisition of germplasm, drying and storage, seed viability monitoring, regeneration, characterization, evaluation, documentation, distribution and exchange, safety duplication, and personnel and security. Each of the sections is supported by a summary diagram depicting these actions in sequential order. An additional section considers the suggested infrastructure and equipment for designing or modifying the facilities of a seed genebank. A final section provides a list of references to provide guidance and/or technical background on seed genebank operations and management. An annex identifies the potential risks associated with the different genebank operations and their respective proposed preventive measures.

B. Draft Practical Guide for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation in Field Genebanks

10. This Draft Practical Guide presents routine operations for the conservation of vegetatively propagated material as whole plants (i.e. Chapter 5 of the Genebank Standards).15 The individual sections provide, respectively, detailed information on the actions and best practices for choice of location of the field genebank, acquisition of germplasm, establishment of field collections, field management, regeneration and propagation, characterization, evaluation, documentation, distribution and exchange, safety duplication, and personnel and security. Summary schema outlining each of the sequential steps required when operating a field genebank are provided for each of the sections. An additional section presents the suggested infrastructure and equipment for designing or modifying field genebank facilities. The final section comprises a list of references providing guidance and/or technical

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12 Brazil, Canada, Democratic Republic of the Congo, Guyana, India, Jordan, Poland, Turkey and the CGIAR Genebank Platform.

13 The underlying principles of genebank management include: 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.

14 Chapter 4: Genebank standards for orthodox seeds.

15 Chapter 5: Field genebank standards.
background on field genebank operations and management. An annex identifies the potential risks associated with the various field genebank operations and their proposed preventative measures.

C. Draft Practical Guide for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture: Conservation of PGRFA via In Vitro Culture

11. The Draft Practical Guide for conservation in in vitro genebanks presents the routine operations for the conservation of vegetatively propagated material as plantlets (i.e. Chapter 6 of the Genebank Standards). The individual sections provide general guidance on the steps and decisions involved in in vitro conservation and cover acquisition of germplasm, in vitro culture and slow-growth storage, recycling and rejuvenation, characterization and evaluation, documentation, distribution and exchange, safety duplication, and personnel and security. Each of these sections is supported by a summary diagram of the workflow of the relevant in vitro genebank activities in sequential order. As with the other two Draft Practical Guides, an additional section considers the suggested infrastructure and equipment for designing or modifying in vitro genebank facilities. A final section provides a list of references to provide guidance and/or technical background on in vitro genebank operations and management. An annex outlines the potential risks associated with the different in vitro genebank operations and their respective proposed preventative measures.

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ANNEX 1. Draft Practical Guide for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture

Conservation of Orthodox Seeds in Seed Genebanks

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1. Introduction

The majority of plant species, including many of the most important food crops, produce orthodox seeds that can be dried to a low moisture content and stored at low temperatures. Lowering seed moisture content and storage temperature extends the storage life of orthodox seeds.

Species that produce orthodox seed and can therefore be conserved in seed genebanks include cereals, grain legumes, forages, most vegetables and some fruits. Most wild relatives of these crops also produce orthodox seeds, although they often require specialized treatment. Some crops that are usually propagated vegetatively, for example potato, also produce true seeds that are orthodox.

Seed 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.17

The conservation of orthodox seeds in genebanks can be broken down into a series of interrelated operations (Figure 1). This practical guide presents practices and activities18 critical to the underlying genebank principles in each operational area (Table 1). It outlines workflows for routine genebank operations for the conservation of orthodox seeds (Figure 2), and supports the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture (Genebank Standards).19 The purpose of this guide is to present the information contained in the Genebank Standards in a format that details the different actions of the genebank workflow in a sequential manner and thereby facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis for the development of Standard Operating Procedures (SOPs)20 and Quality Management Systems21 for conserving germplasm collections, defining in detail how to carry out each activity.

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

18 Practices and activities follow best practices as outlined in the Genebank Standards.
20 For example, see Standard Operation Procedures (SOP) for IITA Seedbank: https://www.iita.org/wp-content/uploads/2017/SOP_for_IITA_Seedbank.pdf
21 https://www.genebanks.org/the-platform/quality-management/
Figure 1. Major operations for the conservation of orthodox seeds in seed genebanks
## Table 1: The underlying principles and related genebank operations for seed genebanks

<table>
<thead>
<tr>
<th>Genebank principle</th>
<th>Summarized genebank operations</th>
</tr>
</thead>
</table>
| Identity of accessions              | Passport data collected and recorded  
                                       | Botanical 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 storage                                                                                                 |
| Maintenance of viability            | Best practices followed and timing optimized during collection, regeneration, seed processing and transportation  
                                       | Storage conditions optimized and monitored  
                                       | Viability monitored regularly  
                                       | Regeneration 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  
                                       | Best practices followed during packing, regeneration and multiplication                                                                                                                                                        |
| Maintenance of germplasm health     | Quarantine procedures undertaken when needed  
                                       | Best practices followed during collection, packing, regeneration and multiplication  
                                       | Contamination monitored and managed                                                                                                                                                                                             |
| Physical security of collections    | Risk management strategy developed and implemented  
                                       | Accessions safety duplicated and safety backed-up  
                                       | Appropriate genebank infrastructure in place and maintained                                                                                                                                                                    |
| Availability and use of germplasm   | Germplasm acquired and distributed according to legal and phytosanitary requirements  
                                       | Sufficient stocks and efficient and timely dispatch of samples  
                                       | 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  
<pre><code>                                   | Data and information generated during genebank activities available to managers and staff                                                                                                                                       |
</code></pre>
<table>
<thead>
<tr>
<th>Well-trained staff employed and protected by occupational safety and health measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genebank staff capacities kept up to date, and training provided as necessary</td>
</tr>
</tbody>
</table>
Figure 2. Flow of germplasm in a seed genebank for orthodox seed conservation. Each step is associated with proper documentation.
2. Acquisition of germplasm

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.

✓ 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.22

- 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.23

The process of germplasm acquisition is governed by national and international regulations.

- The genebank should communicate with the National Focal Points for the International Treaty on Plant Genetic Resources for Food and Agriculture (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)24 can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remain with all material derived from the accession during all genebank handling (viability testing, storage, regeneration and distribution).
- 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.25

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 (MCPD v.2.1). 26

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23 See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf


25 See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf

• 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.

2.1 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:
• 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.27
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.
  o 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.
  o 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)28 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.29

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;³⁰
- passing collected samples through the relevant quarantine process before transferring them to the genebank, if required; and
- multiplying collected accessions with insufficient seed quantity in containment or in an isolated area, according to the advice of the national phytosanitary authority.

✓ Seeds, spikes, pods, etc. are only collected from visibly healthy plants.
In order to prevent potential phytosanitary contamination, avoid, if possible, collecting dispersed seeds from the ground, soiled seeds or seeds infested with saprophytic or pathogenic fungi/bacteria or insects. This may not be possible with crop wild relatives, as they tend to shatter seeds easily.

✓ Seeds, spikes, pods, etc. are collected from an appropriate number of individual plants 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. To attain reasonable representativeness it is recommended to harvest seeds from at least 30 seed parents for cross-fertilizing species and 60 seed parents for autogamous species, if possible.³¹ If the source population is of sufficient size, it is recommended to collect enough seeds to avoid the need for an initial multiplication stage.³² As a general rule, collecting more than 20 percent of the available seeds of a wild population should be avoided in order to leave sufficient seeds for natural population renewal.³³

✓ Collected samples are labelled and are not mixed during handling.
Use indelible ink or computer-generated labels (preferably with barcodes), if possible, on the collection receptacle to label the sample. Placing labels both inside and outside a seed packet is a good practice. Protecting inside labels from deterioration, for example by placing the label in a sealed plastic bag or using moisture resistant labels, is useful if the seed/plant material is not dry. It is recommended to keep a journal with all collection numbers assigned to each sample and additional information, as required.

✓ The period between collecting and processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.³⁴
Initial viability is a major factor in seed sample longevity, and it is at a maximum at the time of harvest/collection; viability declines as seeds begin to age. The sooner the newly harvested seed

³⁰ There are 183 contracting parties to the International Plant Protection Convention, and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/nppos/list-countries/
³¹ See Genebank Standards (Standard 4.1.5): http://www.fao.org/3/a-i3704e.pdf
³² The Crop Genebank Knowledge Base suggests storing a minimum seed quantity of 3 000–4 000 for a genetically homogenous sample, and 4 000–12 000 for a genetically heterogeneous sample: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/conservation-mainmenu-198/seed-bank-mainmenu-199
samples are placed in controlled drying conditions, the more likely it is that a high initial viability will be achieved (see Seed viability monitoring).

✓ **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. If treatments are applied, declare them on each seed package and in accompanying documentation.
  - The use of well-ventilated cloth bags is recommended.

- Use of rigid cushioned envelopes or insulated packaging should protect samples from crushing by mechanical mail sorters and deterioration.

### Transport

- For long transit times by road, periodic aeration of the collected material may be necessary if the seeds/material are moist to prevent potential viability loss.
- Sending shipments using the fastest means possible, by airfreight or courier, should avoid exposure to adverse environmental conditions and deterioration of seed quality.
- Continuous tracking of the package, if possible, will ensure genebank staff are prepared to process the samples upon arrival at the genebank.

✓ **Collected germplasm is accompanied by the associated data outlined in the FAO/Biodiversity Multi-Crop Passport Descriptors.**

A standardized collecting form is helpful for collecting the associated data for each sample obtained. Each sample is assigned a collection number so that the samples can be linked to the collected information. Collecting the following information may be considered:

• Taxonomic identity (species and intraspecific levels, if possible/appropriate), plant population type, habitat and ecology, soil conditions at the collecting site, GPS coordinates and photo images to provide curators and users of the germplasm with an understanding of the environment of origin; associated passport data for each sample obtained as detailed in the FAO/Biodiversity Multi-Crop Passport Descriptors (MCPD v. 2.1),³⁶ if possible (Box 1);

• Information on the origin of the germplasm, traditional knowledge, cultural practices, etc. if collecting from farmers’ fields/stores.

• 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 seed sample and associate it with the accession number in the database.

2.2 Germplasm acquired through transfer/donation

✓ Donated germplasm is legally acquired and accompanied by all relevant documentation.³⁷

• 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,³⁸ it is necessary to use a Standard Material Transfer Agreement (SMTA).³⁹

• 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,⁴⁰,⁴¹ though an 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.

✓ The genebank abides by national, regional and international phytosanitary and any other import regulations and requirements from the relevant authorities.⁴²

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:

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³⁶ Alercia et al. 2015.
³⁸ http://www.fao.org/3/a-bc084e.pdf
³⁹ https://mls.planttreaty.org/itt/
⁴⁰ An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.
• 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; \(^43\)
• passing samples through the relevant quarantine process before they are transferred to the genebank, if required;
• checking donated material for treatment that may require special handling of the seeds, such as breaking dormancy; and
• regenerating donated accessions with insufficient seed quantity in containment or in an isolated area, according to the advice of the national phytosanitary authority.

✔ **Donated germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**\(^44\)

It is recommended to request donors that samples be accompanied by the associated data detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v.2.1).\(^45,46\)

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\(^43\) There are 183 contracting parties to the International Plant Protection Convention, and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/nppos/list-countries/

\(^44\) See Genebank Standards (Standard 4.1.4): http://www.fao.org/3/a-i3704e.pdf

\(^45\) https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

\(^46\) See Box 1.
Figure 3. Summary diagram for acquisition of germplasm
3. Drying and storage

The genebank is recommended to have documented policies and/or procedures, as applicable, for introducing acquired germplasm into long-term and medium-term storage and to ensure sufficient numbers of seeds are available to satisfy requests for timely distribution.

✓ **Collected samples are processed and undergo initial cleaning prior to drying.**

Cleaning samples as part of the initial processing into genebanks is an essential component of sample management. Seeds should be extracted from fleshy and dry fruits, pods and spikes prior to drying. Dry material, particularly for seeds in dry pods or spikes, is threshed to remove seeds from the plant and to break up remaining plant material. If possible, an initial cleaning to remove broken dead seed is done prior to drying.

✓ **Seed samples are dried to optimum moisture content for storage.**

It is recommended dry seeds to equilibrium in a controlled environment of 5−20°C and 10−25 percent relative humidity. The optimal moisture content for storage varies among species, but these conditions should ensure seeds of most species are dried to the optimal moisture content (around 3 percent for oily seeds and 7 percent for starchy cereal seeds). Available online tools can be used to check the equilibrium moisture content achieved under different drying conditions. Where a dedicated drying chamber or room is not available, seeds may be dried using a desiccant such as silica gel. It is helpful to:

- determine the appropriate method for drying seeds, taking into account the type of sample (fleshy fruit, dry fruits or seeds), the number and size of samples to be dried at a time, local climatic conditions and the financial resources available; and
- monitor drying using a digital moisture monitor, indicator silica gel or low-cost dial hygrometers, if available.

✓ **Seeds undergo a final cleaning prior to storage.**

Seeds are threshed to remove them from the remaining plant materials and cleaned to remove broken dead seed prior to storage.

✓ **After drying, samples meant for long-term storage are packaged under controlled conditions, in clearly labelled airtight containers.**

Sealing samples in airtight containers ensures that seeds do not re-absorb moisture during storage. Packaging seeds under dry-room conditions or in an air-conditioned room where relative humidity is controlled is useful in order to maintain the moisture content of the seeds. Additional best practices include:

- filling the container to minimize the air gap above the seeds helps to prevent seeds re-absorbing moisture (ideally keep a range of container sizes to suit the volume of seeds in different accessions);
- using both an outer and an inner label (preferably barcoded) for each sample to ensure that the material is properly identified; and

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47 See Genebank Standards (Standard 4.2.1): http://www.fao.org/3/a-i3704e.pdf
50 See Genebank Standards (Standard 4.2.2): http://www.fao.org/3/a-i3704e.pdf
• storing enough seeds for three regenerations. If enough seed and resources are available, it is recommended to package samples for safety duplication (see Safety Duplication), seed germination testing (see Seed Viability Monitoring) and a reference sample (see below) at the same time.

✓ **Samples of long-term base collections are ideally stored at –18 °C.**  
A suitable temperature for long-term storage is –18 °C. If this technology is not available, sub-zero freezers that do not reach –18 °C are acceptable. For large germplasm collections, a single cold room may be more energy efficient than many standalone freezers. It is very important to have backup power supply for cold stores and freezers. Best practices include:

- avoiding entering cold rooms or opening freezers during any periods of power loss; and
- minimizing the time samples are at higher temperature (but allow containers removed from the cold room or freezer time to equilibrate to the external temperature before opening the container to avoid condensation forming on the cold seeds).

✓ **Samples of medium-term active collections are stored at refrigerated temperatures.**  
Active collections may be stored in purpose-built refrigerated cold stores or commercial refrigerators, ideally at a temperature of 5–10 °C and a relative humidity of 15±3 percent. It is very important to have backup power supply for cold stores and refrigerators. Best practices include:

- avoiding entering cold rooms or opening refrigerators during any periods of power loss; and
- minimizing the time spent at higher temperature (but allow containers to equilibrate to the external temperature before opening to avoid condensation forming on the cold seeds).

✓ **A small reference sample of seeds is kept separately for each accession.**
It is helpful to keep a reference seed sample for each accession in a “seed file”, ideally of the most original sample available. If possible, approximately 50 viable seeds should be kept in a small plastic or glass vial or sealed plastic bag with both an outer and an inner label (preferably

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52 See Genebank Standards (Standard 4.2.3): [http://www.fao.org/3/a-i3704e.pdf](http://www.fao.org/3/a-i3704e.pdf)


54 See Genebank Standards (Standard 4.2.4): [http://www.fao.org/3/a-i3704e.pdf](http://www.fao.org/3/a-i3704e.pdf)
barcoded) to ensure that the material is properly identified. Such a seed sample can be particularly useful for true-to-type verification of seed after regeneration of the accession.

✓ All cleaning, drying and storage data, including associated metadata, are recorded, validated and uploaded to the genebank information management system. Data to consider include accession location (active/base, position within the cold chamber), number of seeds per location, initial moisture content (if available) and date of inclusion in the collection. 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.

55 See Genebank Standards (Standard 4.4.3): http://www.fao.org/3/a-i3704e.pdf
Figure 4. Summary diagram for drying and storage of germplasm
4. Seed viability monitoring

The genebank is recommended to have a documented policy and/or procedure, as applicable, describing the viability monitoring system used to detect falls in viability.

Seed germination testing follows optimized and documented procedures.  
It is important to use standard protocols so that viability monitoring tests are comparable, including over time, ideally using replicated testing procedures. Many genebanks have developed in-house protocols. A number of resources can be found on-line:

- The International Seed Testing Association (ISTA) and the Association of Official Seed Analysts (AOSA) publish germination testing procedures, including suggested substrate, optimum temperature regime, and special treatments that may be required to overcome dormancy.
- Species-specific guidelines for viability testing are available via the Crop Genebank Knowledge Base.
- Kew’s Seed Information Database includes details of successful germination protocols for more than 12 424 wild species, including crop wild relatives.

Initial seed germination testing is conducted as soon as possible after obtaining the accession. All seed lots intended for storage in the genebank should be tested for seed viability. Such testing is particularly important if the seed source indicates that viability may be suboptimal. Well-timed testing provides important data to help inform management decisions about possible early regeneration of poor-quality accessions and minimizes the rate of viability decline between seed collecting and storage.

Some species have a period of primary dormancy and the germination protocol should ensure that dormancy does not confound the result. Older seeds may have secondary dormancy. Literature about specific methods to break seed dormancy must be consulted (see above).

For seeds with very low viability, plant germinated seeds directly for subsequent regeneration if necessary. If the viability is very low, the only way to rescue the accession may be to grow those seedlings that germinated during the viability test. In such cases, transplant germinated seeds directly into pots for growing in the greenhouse or growth chamber, if available. This situation should be prevented, if possible, in order to avoid compromising the genetic integrity of the original sample.

The viability threshold is as high as possible to ensure maximum longevity of the sample. Viability is an important factor in seed longevity, as seeds with high viability tend to survive longer in storage. The standard for minimum viability is generally set at above 85 percent seed germination.

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56 Viability is usually assessed by testing germinability, taking into account dormant seeds that are viable but do not germinate.
57 See Genebank Standards (Section 4.3): http://www.fao.org/3/a-i3704e.pdf
58 https://www.seedtest.org/en/home.html
59 https://www.analyzesseeds.com/
60 https://cropgenebank.sgrp.cgiar.org/images/file/procedures/guidelines%20for%20testing%20germination%20of%20the%20most%20common%20crop%20species.pdf
A lower threshold may be acceptable for certain accessions that do not normally reach 85 percent (for example, some forest and wild species). It may be helpful to consider the following:

- Most seeds that are collected at the optimum stage of maturity, handled appropriately and dried promptly should easily achieve an initial viability of ≥85 percent.
- For those accessions that do not normally reach high levels of seed germination, it is relevant to account for dormant but viable seeds. The use of alternative methods such as cut tests or tetrazolium tests should provide a more accurate estimate of the true viability of the accession.
  - Conducting a cut-test on seeds that have not germinated will help determine whether they seed are dead or diseased. It is recommended, however, to verify this by carrying out a cut-test on fresh seed from the same seed lot.

A monitoring system is in place to test the viability status of samples at regular intervals during storage.

Viability monitoring aims to identify, as closely as possible, the time when viability has fallen to, or is approaching, the determined threshold for regeneration. Setting monitoring intervals is a compromise between the need to avoid wasting seed and resources and the risk that valuable material may be lost if monitoring is too delayed or infrequent. The following practices may be considered:

- determining, as far as possible, optimal testing intervals for maintaining samples above viability thresholds for each species, noting species differences in seed longevity;
- ideally setting viability monitoring test intervals at one-third of the time predicted for viability to fall to the determined regeneration threshold, but not exceeding 40 years;
- setting monitoring intervals for medium-term collections, to 5–10 years for short-lived species; and
- monitoring the viability of the base collection when samples in medium-term storage near the threshold set for regeneration.

The genebank information management system ideally includes automated tools to check viability and flag accessions requiring regeneration.

All seed viability monitoring data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.

Data to consider include dates of germination testing and procedure, number of dead or empty seeds, germination percentage, 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 5. Summary diagram for viability monitoring of germplasm

Seed Viability Monitoring

Seed germination testing follows optimized and documented procedures
- If unknown, research likely germination requirements based on literature, etc.

Seed germination testing is conducted as soon as possible after obtaining the accession
- All seed lots intended for storage in the genebank should be tested for seed viability
- The standard for minimum viability is generally set at above 85 percent seed germination
- If germination falls under this threshold, use tetrazolium or cut-tests to verify dormancy.

The viability threshold is set as high as possible to ensure maximum longevity of the sample

A monitoring system is in place to test viability status of samples at regular intervals during storage
- As far as possible, set optimal testing intervals to maintain samples above viability thresholds for each species, noting species differences in seed longevity

The genebank information management system ideally includes automated tools to check viability and flag accessions requiring regeneration

Record, validate and upload all seed viability monitoring data
5. Regeneration

The genebank is recommended to have a documented policy and/or procedure, as applicable, for regeneration\(^{70}\) of germplasm, including step-by-step instructions for monitoring seed inventory and seed viability, field preparation, selection of accessions, sample size, sowing, crop management, pollination control, identity verification, harvest and post-harvest management and documentation.

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

- **Accessions are regenerated when seed viability or seed quantity falls below the respective regeneration threshold.**
  - Regeneration is required if/when viability falls below the viability threshold or if seed stocks are insufficient to meet distribution requests. An initial regeneration may also be required for newly acquired acquisitions with low seed number. Suggested practices to consider include:
    - regenerating when viability drops below 85 percent of initial viability;\(^{71}\) and
    - regenerating when the number of seeds remaining falls below that required for three sowings of a representative population of the accession.

- **Optimal regeneration procedures are used to minimize risk to the genetic integrity of the accession.**
  - Understanding the genetics and structure of the genebank collection as a whole facilitates informed decisions about regeneration procedures, including species-specific requirements. Best practices to consider include:
    - selecting a regeneration environment that is as ecologically similar as possible to the original collecting site to reduce potential selection pressures;
      - if available, controlled environments such as greenhouses or growth chambers, may also be used.
    - using the most-original sample in storage to regenerate accessions for long-term storage and seeds from the active collection to regenerate accessions for medium-term storage (for a maximum of three cycles, after which a sample of the most-original seeds in long-term storage should be used);
    - creating both hard and electronic copies of field maps developed before planting;
    - clearly labelling regeneration plots (preferably with barcodes);
    - establishing an effective population that represents the genetic composition of the accession;\(^{72}\)
    - following appropriate crop-management practices, including land preparation, any pre-sowing treatments, planting time, plant spacing, irrigation, fertilizer application and pest, disease and weed control;
    - controlling pollination as necessary, for example by taking the crop breeding system into account, which may require physical isolation and provision of pollinating services (insects);
    - removing plants that are growing outside the planted rows;

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\(^{70}\) Note that we are using the term regeneration to depict both multiplication and regeneration to align with the terms use in chapter 4 of the Genebank Standards.

\(^{71}\) See Genebank Standards (Standard 4.4.1): http://www.fao.org/3/a-i3704e.pdf

\(^{72}\) Regeneration guidelines for a number of species are available at the Crop Genebank Knowledge Bank: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/regeneration-mainmenu-206.
• using herbarium specimens and images and reference seed samples, if available, to verify accession identity (true-to-type), including taxonomic identification and verification, and to fill any gaps in documentation;
• removing phenotypically different plants when there is absolute certainty that they are rogue plants derived from contamination of the original accession;
• paying special attention to the regeneration needs of wild species to avoid the complete or partial loss of poorly adapted accessions, for example by growing at alternative locations such as research stations, in greenhouses, or under shaded conditions, etc.;
• observing for occurrence of diseases and pests during regeneration and taking measures to combat them, while avoiding chemical interventions if possible;
• if feasible, taking and storing images of plants and seeds during each regeneration for future reference;
• observing and recording phenotypic heterogeneity that may be based on genotypic heterogeneity
  o consider separating accessions into distinct accessions to ensure diversity is preserved and can be characterized and utilized more efficiently; and
  o record that the separated populations (new accession number/s) are derived from the original accession;73
• adding a specific identifier to the seed lot after harvest that allows all generations of harvested seed lots to be traced to the original material obtained by the genebank;
• taking herbarium specimens and images during the growing season and a small seed sample at harvest to verify accession identity; and
• avoiding mixing and mislabelling during harvest and processing.

✓ All regeneration 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, number of plants harvested, yield, 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 6. Summary diagram for regeneration of germplasm
6. Characterization

The genebank is recommended to have a documented policy and/or procedure, as applicable, for characterization of germplasm, including step-by-step instructions describing field designs, 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.

- Characterization data are obtained for as many accessions as possible and as soon as possible after acquisition.

  Ideally, all accessions should be characterized as soon as possible. The sooner the information is available, the more likely the accession will be used. It is essential that staff be well trained in data recording and field work.

- Characterization can be combined with regeneration.

  For self-pollinating species, accessions can be planted in proximity to each other. In outcrossing species, it is preferable to plant special characterization nurseries using proper isolation methods such as isolation tents. 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;
  - it is advisable to characterize as many accessions as practically possible while remaining efficient;
  - creating both hard and electronic copies of field maps developed before planting; and
  - clearly labelling plots (preferably with barcodes).

- 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.

  The use of standardized crop descriptor lists and calibrated and standardized measuring formats enables the comparison of data across institutions and countries. A wide range of crop descriptor lists have been developed (for example by Bioversity International, The International Union for the Protection of New Varieties of Plants (UPOV), and the National Plant Germplasm System (NPGS) of the United States of America). If there are no existing descriptor lists for a species, it is recommended to use Bioversity International’s Guidelines for Developing Crop Descriptor Lists. It may be helpful to consider:

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74 See Genebank Standards (Standard 4.5.1): http://www.fao.org/3/a-i3704e.pdf
77 See Genebank Standards (Standard 4.5.2): http://www.fao.org/3/a-i3704e.pdf
78 https://www.bioversityinternational.org/e-library/publications/descriptors/
79 https://www.upov.int/test_guidelines/en/
80 https://www.ars-grin.gov/npgs/cgclist.html
• using herbarium specimens and possibly digital high-quality voucher images to guide true-to-type identification, including taxonomic (botanical) identification and verification, if needed;
• observing and documenting the homogeneity/heterogeneity of an accession is important; and
• taking measurements at the plant level rather than at the plot level for crops with high levels of variability in order to capture information about the variability between plants of the same accession.

It may be preferable to split an accession into two or more different accessions that are phenotypically homogenous to facilitate characterization and utilization. If that is done, the composition of the original accession must be properly recorded and documented, and new accession numbers assigned to the newly defined accessions. For some purposes it may be necessary to create pure lines based on single plant offspring in self-pollinating plants.

✓ 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 help identify mislabelled plants and duplications. 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. 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 accessions or varieties used, descriptors measured and results, dates recorded, staff responsible, laboratory techniques (molecular, etc.) and dates carried out. 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 selected data publicly available to potential germplasm users at genebank, country, regional and global levels will serve to enhance germplasm use (see Documentation). The publishing of characterization data is therefore highly recommended.

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84 A number of resources on molecular marker technologies are available online and in print. Please see Further Information/Reading.
Figure 7. Summary diagram for characterization of germplasm
7. Evaluation

The genebank is recommended to have documented policies and/or procedures, as applicable, for the evaluation of germplasm, including step-by-step instructions describing seed sampling methodology, replicated multilocation, 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. 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 and/or field trials, as applicable. 85

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 agro-ecological 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. 86

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

• defining and identifying check 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, virologists, entomologists, mycologists, plant pathologists, chemists, molecular biologists and statisticians) to agree on the traits to be evaluated, the accessions that will 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 maps developed before planting; and
• clearly labelling plots (preferably with bar-codes).

✔ Evaluation data are presented using appropriate methods.

The use of standardized crop descriptor lists and calibrated and standardized measuring formats enables the comparison of data across institutions and countries (see Characterization section). 87 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.

✔ Molecular markers and genomic tools are used if resources are available.

The use of molecular markers in strong linkage with an agronomic trait provides a fast and relatively inexpensive screening methodology for the evaluation of germplasm. Molecular markers 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. 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.

Data to consider include location, planting and harvest dates, cultural practices used (spacing, weeding, irrigation, pesticide application, etc.) and dates when implemented, number of replications, check accessions or varieties used, descriptor measured and results, dates recorded, staff responsible, laboratory techniques (molecular, etc.) and dates carried out. 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 evaluation data are made publicly available. Having selected data publicly available to potential germplasm users at genebank, country, regional and global levels will enhance their use (see Documentation). The publishing of evaluation data will also promote the use of the germplasm collection, especially by plant breeders.

88 A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.
Figure 8. Summary diagram for evaluation of germplasm
8. Documentation

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

✓ **International data standards are adopted to provide consistency in data shared among different information systems and programmes.**

   Recording the passport data of accessions using FAO/Bioversity multicrop passport descriptors (MCPD v.2.1)\(^9\) and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation\(^9\) facilitate data exchange, and comparison of accessions across different countries and institutions. Passport data should ideally be available for all accessions in the genebank collection.\(^9\) A unique and permanent accession number is a key element of proper documentation and identification and must be assigned to each accession upon its acceptance into the genebank collection. In addition, different seed lots or generations of seed accessions should be identified uniquely. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)\(^9\) 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.

✓ **A genebank information management system is used.**

   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 genebank, including passport, characterization, evaluation, seed storage and management data and metadata. Built-in automated tools for checking seed-lot inventory and viability 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.\(^9\) Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),\(^9\) the German Genebank Information System (GBIS)\(^9\) and Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa).\(^9\)

✓ **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 adds to the value and prestige of 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.\(^9\) Genesys allows accession data from genebanks around the world to be shared, and facilitates the ordering of germplasm. It includes accession-level passport, characterization

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\(^9\) See Characterization and Evaluation section.


\(^9\) [https://www.grin-global.org/](https://www.grin-global.org/)

\(^9\) [http://seed.worldveg.org](http://seed.worldveg.org)


\(^9\) [http://alelo.cenargen.embrapa.br/alelo_en.html](http://alelo.cenargen.embrapa.br/alelo_en.html)

\(^9\) [https://www.genesys-pgr.org/welcome](https://www.genesys-pgr.org/welcome)
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).\(^9\) By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals,\(^9\) WIEWS stores and publishes accession-level passport data for the largest global inventory of *ex situ* collections.\(^10\)

- **All data and information relating to all aspects of conservation and use of germplasm, including images and metadata, are validated and uploaded to the genebank information management system.**\(^10\)

  It is important to have staff trained in data recording and data entry in close collaboration with documentation officers and germplasm collection curators. 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. It is recommended that genebank curators and documentation officers validate data before they are uploaded into the genebank information management system.

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

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Figure 9. Summary diagram for documentation
9. Distribution

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 authority, as necessary.

✓ The genebank complies with national, regional and international regulations and agreements.\(^{102}\)

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\(^{103}\) are being distributed for the intended uses covered by the Treaty (i.e. research, breeding and training for food and agriculture), it is necessary to use an SMTA.\(^{104}\)
- 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 the material or its derivatives, data reporting, etc. An MTA is usually used,\(^{105,106}\) though an SMTA could also be used.

✓ A policy is in place for the number of seeds to distribute for any given species.

For most species, a sample of 100–200 viable seeds would be supplied for those accessions with sufficient seeds.\(^{107}\)

- For accessions with too few seeds at the time of the 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 seeds is sufficient.
- If feasible, consider the distribution of samples with a mutually signed regeneration agreement. In this case, the requesting institute should have the necessary technical capacity and regeneration should be carried out under the supervision of staff from the genebank according to the genebank’s protocols.

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\(^{103}\) http://www.fao.org/3/a-bc084e.pdf

\(^{104}\) https://mls.planttreaty.org/itt/

\(^{105}\) An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.


\(^{107}\) See Genebank Standards (Standard 4.8.4): http://www.fao.org/3/a-i3704e.pdf
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.

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 seeds and the dispatch of the seeds is kept to a minimum.108

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 seed packet to ensure that the material is properly identified.

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.109
Consider scanning documents and sending them by e-mail, or sending hard copies by mail, prior to the dispatch of the germplasm. Items of documentation to consider include:
- data on accessions (including an itemized list with accession identification, seed lot/generation identification, number and/or weight of samples, and key passport data); and
- import permit, phytosanitary certificate or customs declaration, if appropriate.

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 (see Acquisition section).

The delivery of the germplasm and its condition on arrival at its destination is checked by following up with the recipient.
Tracking the shipment and following up with the recipient on the status and performance of the distributed germplasm is recommended.

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, number of seeds per sample and/or weight; reference to

phytosanitary certificate and SMTA\textsuperscript{110} or MTA\textsuperscript{111} 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 bar-code labels and barcode readers facilitates accession management and minimizes human error.

\textsuperscript{110} https://mls.planttreaty.org/itt/

Figure 10. Summary diagram for distribution of germplasm

1. Genebank complies with national, regional and international regulations and agreements
   - Use SMTA if signatory to Treaty and Annex 1 material
   - If SMTA is not applicable, negotiate MTA with recipient (SMTA can also be used)
2. Have a policy in place for the number of seed to distribute for any given set of germplasm
   - Regeneration may be necessary for accessions with too few seed
3. Required documentation is requested and obtained
   - Request import permit regulations from the relevant national authority of the receiving country
4. Arrangement with National Plant Protection Officers for germplasm inspection and issuance of Phytosanitary Certificate
   - Use computer-produced labels to reduce transcription errors
   - Place labels both outside and inside each packet
5. Samples carefully labeled and not mixed during handling
6. Required documentation is placed both inside and outside of shipping package
   - Include accession data (accession identification, number of samples, weight, number of seeds and key passport data); import permit, phytosanitary certificate and/or customs declaration
   - Send scanned documents in advance by email to the recipient
7. Packaging material and transport allows for safe and timely delivery
   - Use of packing and shipping guidelines/recommendations similar to those utilized for acquisition
8. Follow-up with recipient on status and performance of material
9. Record, validate and upload all distribution and exchange data
10. Safety duplication

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.

✔ A safety duplicate sample for every original accession is stored at a distant location, under appropriate conditions and utilizing best practices.

Safety duplicates are generally deposited in a base collection at a different location, usually in another country. Safety duplication can also involve the placement of accessions in a genebank where they are actively managed. The safety duplicate location is chosen so as 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. In addition, many genebanks send “black box” samples to the Svalbard Global Seed Vault or other institutes, as a safety backup. In such cases, the recipient only stores the materials in their long-term base storage facility and should not open the boxes or seed packages.

✔ A legal agreement between the depositing and recipient genebanks that clearly specifies the terms and conditions under which material is maintained and managed is in place.

✔ 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 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 to consider include:

• ensuring duplicated material is clean and healthy and has a high initial viability;
• ensuring that the safety-duplicated samples are large enough to allow at least three regenerations to be conducted;\(^{112}\)
• including a subset of materials to be used for viability testing in the future; and
• using viability monitoring data for seeds from the same seed lot stored in the originating genebank’s base collection to determine whether viability monitoring of the safety duplicate sample should commence (if samples are included for monitoring) or otherwise whether the safety duplicate sample should be replaced.

✔ Samples are labelled carefully and are not mixed during handling.

It is important to use seed packets that are durable and impervious to moisture in order to maintain viability and that samples are correctly labelled, preferably with computer-produced labels, to reduce transcription errors in names and numbers.

\(^{112}\) If possible, a safety duplicate of an accession in a seed genebank should contain at least 500 viable seeds for cross-pollinating species and a minimum of 300 seeds for genetically uniform accessions (see Genebank Standards Section 4.9).
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). Best practices include:

- packing all seed samples for safety duplication in clearly labelled, vacuum-sealed trilaminate aluminium foil packets seamed on all four sides with no gusset;
- including an outer and inner label for each packet to ensure that the material can be properly identified; and
- using packaging and shipping guidelines/recommendations similar to those used for distribution is recommended (see Distribution sections).

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 number, DOI if available, key passport data, total quantity of seeds (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.

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; packing date, samples sent, seed number and/or per sample and packaging information; 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 to ensure that any new accessions not safety duplicated are identified and prepared for safety duplication, as appropriate.

Figure 11. Flow diagram for safety duplication of germplasm
11. Personnel and Security

**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.

- 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.\(^{114}\) 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;
  - 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 every-day environment to which the 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.\(^{115}\) 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:\(^{116}\)

    - **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;

---

\(^{114}\) See Genebank Standards (Standard 4.10.3): http://www.fao.org/3/a-i3704e.pdf

\(^{115}\) See Genebank Standards (Standard 4.10.1): http://www.fao.org/3/a-i3704e.pdf

• **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; and
• **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.

✓ **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.\(^\text{117}\) Most countries will have an OSH policy. The International Labour Organization (ILO)\(^\text{118}\) 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 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.

\(^{117}\) See Genebank Standards (Standard 4.10.2): http://www.fao.org/3/a-i3704e.pdf

\(^{118}\) https://www.ilo.org/global/lang--en/index.htm
Figure 12. Summary diagram for personnel and security
12. Infrastructure and equipment

This section considers the suggested infrastructure and equipment for a seed genebank (Table 2). The long-term storage of orthodox seeds is based on reduction in seed moisture content followed by hermetic storage at low temperature. The seed genebank infrastructure is therefore centred around seed drying and storage facilities, together with laboratory, glasshouse, field and office facilities for associated operations such as seed cleaning, viability testing, plant health testing, regeneration, characterization and evaluation, documentation and seed distribution (Table 2).

Factors to be considered when designing or modifying genebank facilities include: (a) the function of the facility (research, medium- and long-term storage); (b) the projected throughput and number, volume and weight of accessions for storage; (c) the expected distribution rates; (d) the local climate (of particular importance in the tropics because of potential contamination issues); and (e) the number of qualified staff.

A useful case study from India calculated the costs of establishing seed genebank facilities, and acquiring, processing, storing (medium- and long-term), monitoring and regenerating germplasm.\textsuperscript{119} The Millennium Seed Bank’s series of technical information sheets provides some helpful background information and specifications for key seed genebank activities and areas.\textsuperscript{120} It is important to note that costly facilities are not always required – high-quality, small-scale seed banking can be accomplished with simple desiccation drying techniques and domestic refrigerators/freezers.

Table 2. General infrastructure and equipment recommended for a seed genebank

<table>
<thead>
<tr>
<th>Genebank operation/management area</th>
<th>General needs</th>
<th>Acquisition</th>
<th>Drying and storage</th>
<th>Seed viability monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General needs</strong></td>
<td>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.</td>
<td>Collecting equipment including cloth and/or paper bags, labels (ideally barcoded), hand lenses, scissors, secateurs, tarpaulins, packaging materials, herbarium presses, simple desiccation drier.</td>
<td>Dry room and associated plant room and/or other appropriate drying facilities, digital humidity monitor or other means of measuring moisture status.</td>
<td>Germination test facilities including media preparation area, test set-up/scoring area, dissection equipment, microscopes, controlled environment facility (plant growth room, germination</td>
</tr>
<tr>
<td><strong>Acquisition</strong></td>
<td>Collecting data sheets or mobile devices for electronic data recording, GPS or altimeter.</td>
<td></td>
<td>Hermetic containers or tri-laminate foil bags/bag sealer for long-term storage, airtight easily opened containers for medium-term storage, labels (ideally barcoded), balances, seed counter, data sheets or mobile devices for electronic data recording, barcode reader.</td>
<td></td>
</tr>
<tr>
<td><strong>Drying and storage</strong></td>
<td></td>
<td>Cold room(s) including plant room for refrigeration equipment and shelving system and/or refrigerators, thermostat, low temperature alarm, personnel panic button.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seed viability monitoring</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


\textsuperscript{120} https://brahmsonline.kew.org/msbp/Training/Resources
chamber(s), incubator(s)), viability test sheets, data sheets or mobile devices for electronic data recording, barcode reader.

<table>
<thead>
<tr>
<th>Regeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to field or glasshouse areas, as required.</td>
</tr>
<tr>
<td>Isolation tents; overwintering storage for biennial vegetables; fenced area for perennial nurseries.</td>
</tr>
<tr>
<td>Pollinator-rearing equipment/incubators as required.</td>
</tr>
<tr>
<td>Growth chambers if required for quarantine.</td>
</tr>
<tr>
<td>Field/glasshouse equipment and machinery, as necessary, according to species.</td>
</tr>
<tr>
<td>Plot stakes and labels (ideally barcode labels), labelled cloth bags or other appropriate containers.</td>
</tr>
<tr>
<td>Data sheets or mobile devices for electronic data recording, barcode reader.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characterization and evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to field, lab or glasshouse areas, as required.</td>
</tr>
<tr>
<td>Field/lab/glasshouse equipment and machinery, as necessary, according to the species and traits being recorded.</td>
</tr>
<tr>
<td>Plot stakes and labels (ideally barcode labels), labelled cloth bags or other appropriate containers.</td>
</tr>
<tr>
<td>Molecular analysis (RAPD, ISSR, SSR) equipment, if possible.</td>
</tr>
<tr>
<td>Data sheets or mobile devices for electronic data recording, barcode reader.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable designed database/genebank information management system aligned to FAO/Bioversity MCPDs and other data standards, e.g. GRIN-Global.</td>
</tr>
<tr>
<td>Database with built-in automated tools for checking seed-lot inventory and viability and flagging accessions requiring regeneration.</td>
</tr>
<tr>
<td>Data backup/storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distribution and safety duplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balances, seed counter, tri-laminate foil bags, bag sealer, labels (preferably barcoded), packing materials.</td>
</tr>
<tr>
<td>Data sheets or mobile devices for electronic data recording, barcode reader.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Security and personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator(s), fire-extinguishing equipment, security cameras, alarm systems, security doors.</td>
</tr>
<tr>
<td>Protective clothing and protective gear such as dust masks, gloves and footwear.</td>
</tr>
</tbody>
</table>
13. 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.

General references


Acquisition and distribution


**Biodiversity International.** 2009. *Descriptors for farmers’ knowledge of plants.*
https://cgspace.cgiar.org/handle/10568/74492

**CBD, 2018.** Frequently Asked Questions on Access and Benefit-Sharing (ABS).


http://www.abctaxa.be/volumes/volume-8-manual-atbi


http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/02-Assessing-population.pdf


Sheppard, J.W. & Cockerell, V. 1996. ISTA handbook of method validation for the detection of seedborne pathogens. Basserdorf, Switzerland, ISTA.


Drying and storage


Viability monitoring


http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/13a-Germination-testing-procedures.pdf


Regeneration


Characterization and evaluation


Molecular characterization and evaluation


Documentation


Safety duplication

Nordgen. 2008. Agreement between (depositor) and the Royal Norwegian Ministry of Agriculture and Food concerning the deposit of seeds in the Svalbard Global Seed Vault. The Svalbard Global Seed Vault.

Infrastructure and equipment


http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/13b-Germination-testing-dormancy.pdf

http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/14-Seed-cleaning.pdf

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.

Acquisition

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

Drying and storage

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced seed longevity due to moisture uptake during packing</td>
<td>• Pack seeds in a controlled, dry environment</td>
</tr>
<tr>
<td>Reduced seed longevity and earlier regeneration due to container leakage</td>
<td>• Leak-test every new batch of packaging material.&lt;br&gt; • Ensure the sealing machine is working properly&lt;br&gt; • Ensure screw caps are adequately tightened&lt;br&gt; • Set up a monitoring system to periodically measure the moisture content of randomly selected samples from the genebank and of any accessions removed for testing or distribution</td>
</tr>
<tr>
<td>Mixing/mislabelling of samples</td>
<td>• Pack carefully to avoid mixing&lt;br&gt; • Place labels inside and outside of packets&lt;br&gt; • Use computer-generated barcode labels to minimize errors</td>
</tr>
<tr>
<td>Stored samples falling below viability or quantity thresholds</td>
<td>• Ensure that the documentation system includes automated tools for monitoring seed-lot viability and inventory and flag accessions requiring regeneration</td>
</tr>
<tr>
<td>Inadequate storage temperature due to power failure</td>
<td>• Ensure backup generators and fuel are available</td>
</tr>
</tbody>
</table>
Seed viability monitoring

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| True viability of accessions is not reflected during germination testing | • Optimize germination testing and dormancy breaking methods.  
• Use replicated testing procedures  
• Carry out cut tests to identify seeds that are still firm/fresh to estimate the viability of dormant accessions  
• Out-source of germination testing if necessary |
| Inappropriate viability testing intervals result in depletion of seeds or significant fall in viability | • Use all available viability-monitoring data (for example, germination rate, and number of abnormal seedlings) for the accession and collection to set appropriate monitoring intervals.  
• Consider shortening the monitoring intervals when seed lots are known/predicted to be approaching the viability threshold. |

Regeneration

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| Loss of adaptive alleles due to selection pressures | • Regenerate under controlled environmental conditions  
• Regenerate at a site with a similar climate to that of the collection site where the material originated  
• Outsource regeneration |
| Loss of purity due to cross-pollination from other accessions of the same species or from nearby crops | • Follow recommended crop-specific isolation distances or use isolation cages, bagging or other pollination-control measures |
| Poor levels of pollination | • Use pollination cages to enclose insect pollinators  
• Ensure adequate availability of insect pollinators  
• Hand pollinate as required/possible |
| Misidentification of samples | • Check plot and bag labels prior to sowing and harvesting; use barcodes |
| Loss of purity due to contamination/mixing of seed samples during seed preparation, sowing, harvesting and post-harvest handling | • Carefully inspect and clean all machinery between each processing step  
• Compare harvested material against reference material for the regenerated accessions |

Characterization and evaluation

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| 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 samples | • Check plot labels while collecting data  
• Check plot and bag labels prior to sowing and harvesting |
## Distribution

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing/mislabelling of samples</td>
<td>• Pack carefully to avoid mixing</td>
</tr>
<tr>
<td></td>
<td>• Use labels on the inside and the outside of seed packets</td>
</tr>
<tr>
<td></td>
<td>• Use computer-generated barcode labels to minimize errors</td>
</tr>
<tr>
<td>Viability loss due to delayed or damaged shipments</td>
<td>• Pack seeds in suitable packaging to minimize uptake of moisture.</td>
</tr>
<tr>
<td></td>
<td>• Ensure seeds are dispatched promptly, and use the fastest and safest way of sending them.</td>
</tr>
</tbody>
</table>

## Safety duplication

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing/mislabelling of samples</td>
<td>• Packing carefully to avoid mixing</td>
</tr>
<tr>
<td></td>
<td>• Use labels used on the inside and the outside of seed packets</td>
</tr>
<tr>
<td></td>
<td>• Use computer-generated barcode labels to minimize errors</td>
</tr>
<tr>
<td>Viability loss due to delayed or damaged shipments</td>
<td>• Ensure seeds are dispatched promptly and use the fastest and safest way of sending them.</td>
</tr>
<tr>
<td></td>
<td>• Assess the likelihood of significant decline in viability based on a worst-case scenario of conditions during transport (in particular temperature if the seeds are in air-tight moisture-proof packets).</td>
</tr>
<tr>
<td></td>
<td>• Include viability monitoring samples and agree on whether these will be tested by the recipient or returned to the sending institution</td>
</tr>
</tbody>
</table>
ANNEX 2. Draft 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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1. Introduction

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 life spans 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 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 the 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.

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 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). The purpose of this guide is to present the information contained in the Genebank Standards in a format that details the different actions of the genebank workflow in a sequential manner and thereby facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis for developing Standard Operating Procedures (SOPs) and Quality Management Systems for conserving germplasm collections, defining in detail how to carry out each activity.

123 Practices and activities follow best practices as outlined in the Genebank Standards.
125 For example, see Standard Operation Procedures (SOP) on Field Conservation and Regeneration of Agroforestry Tree Genetic Resources at ICRAF: http://old.worldagroforestry.org/products/grunew/downloads/SOP_ICRAF_Field_Genebank_Conservation_Regeneration.pdf
126 https://www.genebanks.org/the-platform/quality-management/
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.

Figure 1. Major operations for conservation in field genebanks
Table 1: The underlying principles and related genebank operations for field genebanks

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

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.

- The site of the field genebank has agro-ecological conditions as similar as possible to the environment where the conserved plant materials originated.\(^{127}\)
  - 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.

- The site is in a location that minimizes risks from natural and human-made disasters.\(^{128}\)
  - 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;
    - 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 is secure over the long term (minimum of 50 years) based on written, guaranteed renewal or gazetted land tenure.\(^{129}\)
  - 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 site is within easy transport distance for curational staff and field labourers.\(^{130}\)
  - Easy physical access to the field genebank site facilitates field and plant management and regular monitoring.

- The land area selected for the field genebank is suitable for using mechanized mulching and both fertilizer and pesticide applications.

- The site has easy access to a water source for necessary pesticide applications and, as required, for supplemental irrigation.

- The site has access to facilities for propagation and raising plants in nurseries.

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\(^{127}\) See Genebank Standards (Standard 5.1.1): http://www.fao.org/3/a-i3704e.pdf

\(^{128}\) See Genebank Standards (Standard 5.1.2): http://www.fao.org/3/a-i3704e.pdf

\(^{129}\) See Genebank Standards (Standard 5.1.4): http://www.fao.org/3/a-i3704e.pdf

\(^{130}\) See Genebank Standards (Standard 5.1.5): http://www.fao.org/3/a-i3704e.pdf
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.\(^{131}\) 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.

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.

\(^{131}\) See Genebank Standards (Standard 6.1.1): http://www.fao.org/3/a-i3704e.pdf
Figure 3. Summary diagram for choice of location of field genebank

- Commercial production of target crop nearby is good indication
- Community development plan does not foresee major land-use change
- Maintain a distance of at least 10 km distance from active volcanoes
- Avoid sites in the prevailing path of hurricanes, typhoons
- Avoid areas close to human settlements and/or known to have civil strife
- Choose site where previously not used for same crop to avoid soil-borne diseases
- Safe isolation distance from crops and wild populations with which it can cross-pollinate
- Easy access to a water source for necessary pesticide applications and supplemental irrigation
3. Acquisition of germplasm

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.

✓ **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.\(^{132}\)

- 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.**\(^ {133}\)

The process of germplasm acquisition is governed by national and international regulations.

- The genebank should communicate with the National Focal Points for the International Treaty on Plant Genetic Resources for Food and Agriculture (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)\(^ {134}\) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remain with all material derived from the accession during all genebank handling (viability testing, storage, regeneration and distribution).
- 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.**\(^ {135}\)

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 (MCPD v.2.1).\(^ {136}\)

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\(^ {133}\) See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf


\(^ {135}\) See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf

• 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:

• 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.137

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.
  o 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.
  o 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)138 determined, according to relevant national, regional or international laws and regulations.

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137 See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf

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 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;¹³⁹
• 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.

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.¹⁴₀

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 plants¹⁴¹ 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.¹⁴²

• It is recommended to harvest from at least 30 individuals for cross-fertilizing species and 60 individuals for autogamous species, if possible.
  o For roots and tubers, collect a minimum of four propagules for each sample, more if culturing techniques for the species are not reliable.¹⁴³
  o 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.¹⁴⁴

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.

¹³⁹ There are 183 contracting parties to the International Plant Protection Convention, and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/nppos/list-countries/
¹⁴₀ See Genebank Standards (Standard 5.2.3): http://www.fao.org/3/a-i3704e.pdf
¹⁴² The Crop Genebank Knowledge Base provides very useful information on collecting: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting
The period between collecting, processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.\textsuperscript{145} 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.\textsuperscript{146} 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.
- 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.

**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.

\textsuperscript{145} See Genebank Standards (Standard 5.2.4): http://www.fao.org/3/a-i3704e.pdf

\textsuperscript{146} 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.
Collected germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.147

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 (MCPD v.2.1) (Box 1);148
- Information on the origin of the germplasm, traditional knowledge, cultural practices, etc. if collecting from farmers’ fields/stores; and
- 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.

All incoming material is checked for damage/contamination in a designated reception area and processed in a way that does not alter the physiological status.149

- 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 micro-organisms, 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.150

- 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,151 it is necessary to use a Standard Material Transfer Agreement (SMTA).152

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147 See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf
149 See Genebank Standards (Standard 5.2.5): http://www.fao.org/3/a-i3704e.pdf
150 See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf
151 http://www.fao.org/3/a-bc084e.pdf
152 https://mls.plantrtreaty.org/itt/
• 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,\textsuperscript{153,154} 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.

√ 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;\textsuperscript{155}:

• 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 way that does not alter the physiological status.\textsuperscript{156}

• 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 micro-organisms, taking into account any decontamination treatment given prior to packaging and transport.

• Quarantine measures are applied, as necessary.

√ Donated germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.\textsuperscript{157}

• It is recommended to request donors that samples be accompanied by the associated data detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v.2.1).\textsuperscript{158,159}

\textsuperscript{153} An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.


\textsuperscript{155} There are 183 contracting parties to the International Plant Protection Convention, and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/npos/list-countries/

\textsuperscript{156} See Genebank Standards (Standard 5.2.5): http://www.fao.org/3/a-i3704e.pdf

\textsuperscript{157} See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf

\textsuperscript{158} https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

\textsuperscript{159} See Box 1.
Figure 4. Summary diagram for acquisition of germplasm
4. Establishment of field collections

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.

✓ The field is prepared to further safeguard the collection.

In addition to choosing a site that minimizes risks from natural and human-made disasters,\(^{160}\) 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 use 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.

✓ 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,\(^{161}\) 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.

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\(^{160}\) See section: Choice of Location of the Field Genebank.

\(^{161}\) See Genebank Standards (Standard 5.3.2): http://www.fao.org/3/a-i3704e.pdf
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.**
  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;\(^{163}\)
  - owing 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;\(^ {164}\) and
  - 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.**
  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;\(^ {166}\)
  - 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.

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162 See Genebank Standards (Standard 5.3.1): http://www.fao.org/3/a-i3704e.pdf

163 Guidelines can be extrapolated from germplasm collection practices. The Crop Genebank Knowledge Base provides very useful information on collecting: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collection

164 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.

165 See Genebank Standards (Standard 5.3.3): http://www.fao.org/3/a-i3704e.pdf

166 Note: FAO has published crop calendars for Latin America and Africa that are helpful in this regard: http://www.fao.org/agriculture/seed/cropcalendar/welcome.do
• 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.

✓ 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 for establishment of field collections
5. Field management

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.

✓ Cultural practices necessary for optimum plant growth and maintenance are followed. 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.

✓ 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. 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:
    o monitor field collections regularly to ensure that each accession and each plant within the accession is properly identified;
    o periodically verify accession labels with the field map;
    o compare individual plants within each accession to plot plans; and
    o 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. 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.

167 See Genebank Standards (Standard 5.4.2): http://www.fao.org/3/a-i3704e.pdf
168 See Genebank Standards (Standard 5.4.3): http://www.fao.org/3/a-i3704e.pdf
169 See Genebank Standards (Standard 5.4.1): http://www.fao.org/3/a-i3704e.pdf
✓ **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 (ELISA, DNA-based such as RT-PCR)
- cleaning any infected clonal materials by thermotherapy and/or tissue culture;
- 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 for field management
6. Regeneration and propagation

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.

- **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. \(^{170}\)
  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. \(^{171}\)

- **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 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. \(^{172}\)

- **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. \(^{173}\)
  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; \(^{174}\)
  - storing propagation materials in special facilities (e.g. greenhouses, *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; \(^{175}\) 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:
  - *Pre-treatment:* It is essential that storage propagules are free of damage caused by insects and nematodes and any other visible symptoms of diseases before storage. It is therefore necessary to disinfect the storage propagules after harvest and before storage.

\(^{170}\) See section on Establishment of Field Collections for general guidelines.

\(^{171}\) See Genebank Standards (Standard 5.5.1): http://www.fao.org/3/a-i3704e.pdf

\(^{172}\) Note: FAO has published crop calendars for Latin America and Africa which are helpful in this regard: http://www.fao.org/agriculture/seed/cropcalendar/welcome.do

\(^{173}\) See Genebank Standards (Standard 5.5.2): http://www.fao.org/3/a-i3704e.pdf

\(^{174}\) See Roots of Peace (2007) for examples of propagation techniques.

\(^{175}\) Note: This practice is only recommended when the collection is free from major root and leaf diseases.
Cold storage of planting material: 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.

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.

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. 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.

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.

176 See Genebank Standards (Standard 5.5.2): http://www.fao.org/3/a-i3704e.pdf
177 See Genebank Standards (Standard 5.5.3): http://www.fao.org/3/a-i3704e.pdf
Figure 7. Summary diagram for regeneration and propagation
7. Characterization

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.

- **Characterization data are obtained for as many accessions as possible and as soon as possible.**
  Ideally, all accessions should be characterized. The first opportunity for characterization is during germplasm collection. For all species, it is important to characterize a representative number of plants per accession. 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.

- **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;
  - creating both hard and electronic copies of field maps developed before planting; and
  - clearly labelling plots (preferably with barcodes).
  It is advisable to characterize larger number of accessions 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.**
  The use of standardized crop descriptor lists and calibrated and standardized measuring formats enables the comparison of data across institutions and countries. A wide range of crop descriptor lists has been developed (for example by Bioversity International, The International Union for the Protection of New Varieties of Plants (UPOV), and the National Plant Germplasm System (NPGS) of the United States of America). If there are no existing

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179 See Genebank Standards (Standard 5.6.2): http://www.fao.org/3/a-i3704e.pdf
182 See Genebank Standards (Standard 5.6.3): http://www.fao.org/3/a-i3704e.pdf
183 See Genebank Standards (Standard 5.6.4): http://www.fao.org/3/a-i3704e.pdf
184 https://www.bioversityinternational.org/e-library/publications/descriptors/
185 https://www.upov.int/test_guidelines/en/
186 https://www.ars-grin.gov/npgs/cgclist.html
descriptor lists for a species, it is recommended to use Bioversity International’s Guidelines for Developing Crop Descriptor Lists.\(^{187}\) 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 (botanical) identification and verification, if needed;
- observing 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.


Molecular marker technologies and genomic tools for characterization are utilized if resources are available, complementing phenotypic characterization.\(^{188}\) Molecular markers help ensure the identity of plants and to identify mislabelled plants and duplications.\(^{188}\) 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.\(^{189}\) 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). The publishing of characterization data is therefore highly recommended.

\(^{188}\) See Genebank Standards (Standard 5.6.3): http://www.fao.org/3/a-i3704e.pdf

\(^{189}\) A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.
Figure 8. Summary diagram for characterization of germplasm
8. Evaluation

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 multilocation, multi-year 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. 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 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 agro-ecological 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.**
  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, 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 maps developed before planting; and
  - clearly labelling plots or greenhouse 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

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190 See Genebank Standards (Standard 5.7.3): http://www.fao.org/3/a-i3704e.pdf
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.\footnote{A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.} 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.**\footnote{See Genebank Standards (Standard 5.7.2): http://www.fao.org/3/a-i3704e.pdf}
  
  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 staff responsible. 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 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). The publishing of evaluation data will also promote the use of the germplasm collection, especially by plant breeders.
Figure 9. Summary diagram for evaluation of germplasm
9. Documentation

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

- **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 (MCPD v.2.1)\(^ {193}\) and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation\(^ {194}\) facilitate data exchange and comparison of accessions across different countries and institutions. Passport data are ideally available for all accessions in the genebank collection.\(^ {195}\)

  A unique and permanent accession number is a key element of proper documentation and identification. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)\(^ {196}\) 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.

- **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.\(^ {197}\) Built-in automated tools for checking inventory and viability and flagging accessions requiring regeneration should be available.

  GRIN-Global has been developed by USDA-ARS, the Crop Trust and Bioversity International to enable genebanks to store and manage information associated with plant genetic resources, and is freely available.\(^ {198}\) Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),\(^ {199}\) the German Genebank Information System (GBIS),\(^ {200}\) and Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa).\(^ {201}\)

- **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

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\(^ {193}\) https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

\(^ {194}\) See Regeneration, Characterization and Evaluation section.

\(^ {195}\) See Genebank Standards (Standard 5.8.1): http://www.fao.org/3/a-i3704e.pdf

\(^ {196}\) https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

\(^ {197}\) See Genebank Standards (Standards 5.8.1 and 5.8.2): http://www.fao.org/3/a-i3704e.pdf

\(^ {198}\) https://www.grin-global.org/

\(^ {199}\) http://seed.worldveg.org

\(^ {200}\) http://www.ipk-gatersleben.de/en/genebank/genebank-documentation/genebank-information-system

\(^ {201}\) http://alelo.cenargen.embrapa.br/alelo_en.html
Diversity Trust. 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). By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals, WIEWS stores and publishes accession-level passport data for the largest global inventory of ex situ collections.

 ✓ 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. 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.

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

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202 https://www.genesys-pgr.org/welcome
204 https://unstats.un.org/sdgs/metadata?Text=&Goal=2&Target=2.5
206 See Genebank Standards (Standard 5.8.3): http://www.fao.org/3/a-i3704e.pdf
A suitably designed genebank information management system is used

- Adopt international data standards for consistency in data sharing
- If possible, use mobile devices to capture
- Document passport data using MCPD v. 2.1
- Document collection establishment and management data
- Record regeneration and propagation activities/data
- Document characterization and evaluation data
- Document germplasm orders, distribution data and user feedback
- Document safety duplication data
- Digitize paper data
- Make data publically available, possibly through a search-query database
- Data kept up-to-date at all times
- Duplicate data at regular intervals and store at remote site for security reasons
- Barcoding facilitates accession management
- Consider using DOIs
- Regularly update physical inventory
- Document cultural practices as reference information
- Built-in automated tools to check inventory and viability, and flag accessions requiring regeneration
- Record and make molecular and genomic data available, if applicable/possible

Figure 10. Summary diagram for documentation
10. Distribution

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 fulfillment 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.

- The genebank complies with national, regional and international regulations and agreements.\(^{207}\)
  
  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\(^ {208}\) is being distributed for the established intended uses (i.e. research, breeding and training for food and agriculture), it is necessary to use a Standard Material Transfer Agreement (SMTA).\(^ {209}\)
  
  - 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 to come to an agreement with the recipient on the terms and conditions of germplasm distribution, usually through a Material Transfer Agreement (MTA).\(^ {210, 211}\)

- 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.

- 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-grown material (ex vivo).
    - Examples include sterilizing using bleach solution, hot water treatment and treatment with ozone dissolved in water.\(^ {212}\)
  
  - 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-

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\(^{207}\) See Genebank Standards (Standard 5.9.1): http://www.fao.org/3/a-i3704e.pdf

\(^{208}\) http://www.fao.org/3/a-bc084e.pdf

\(^{209}\) https://mls.planttreaty.org/itt/; http://www.fao.org/3/be494e/be494e.pdf

\(^{210}\) An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.


\(^{212}\) See: Umber et al. https://doi.org/10.3390/v12101101
PCR) and non-radioactive probe-based nucleic acid spot hybridization (NASH) techniques were developed and validated for routine testing.  

✔ **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.

✔ **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.

✔ **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.**
Consider scanning documents and sending them by e-mail, or sending hard copies by mail, prior to the dispatch of the germplasm. Documentation to consider includes:

- data on accessions (including an itemized list with accession identification, number of samples, and key passport data); and

- import permit, phytosanitary certificate or customs declaration, if appropriate.

✔ **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.

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

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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\textsuperscript{216} or MTA\textsuperscript{217} 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.

\textsuperscript{216} https://mls.planttreaty.org/itt/

Figure 11. Summary diagram for distribution of germplasm
11. Safety duplication

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.\textsuperscript{218}

- 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.\textsuperscript{219}

  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 \textit{in vitro}\textsuperscript{220} conditions for the duplicated accessions. Alternatively, samples can be cryopreserved at the duplicating centre.\textsuperscript{221} The selection of, and clear agreement with, the chosen holder of the safety duplicate are critical.

- 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 be help 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:
  \begin{itemize}
  \item duplicating clean and healthy material; and
  \item ensuring that safety-duplicated samples are large enough to avoid risk of loss.\textsuperscript{222}
  \end{itemize}

- 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.

\begin{itemize}
\item Duplicated material includes plants to be managed in the field, plantlets maintained \textit{in vitro} or meristematic tissues under cryopreservation.
\item See Genebank Standards (Standard 5.10.4): http://www.fao.org/3/a-i3704e.pdf
\item See the Draft Practical Guide for the conservation of PGRFA via \textit{in vitro} culture and Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf
\item See Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf
\item 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.
\end{itemize}
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 e-mail, or sending hard copies by mail, prior to the dispatch of the germplasm.

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 for safety duplication of germplasm
12. Personnel and security

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.

✓ 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. 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;
- 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 every-day environment to which the 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. 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:

- 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; and
• **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.

✓ **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. Most countries will have an OSH policy. The International Labour Organization (ILO) 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 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.

---

Figure 13. Summary diagram for personnel and security

- Ensure necessary staff skills
- Conduct regular staff training (on-the-job & external)
- Rotate tasks to make work more varied and interesting
- Retain staff by providing recognition and incentives

Communication and consultation
Establishing the context
Risk identification
Risk analysis
Risk evaluation
Risk treatment
Monitoring and review

Risks to Staff
- Take health and safety of staff and environment into consideration when applying pesticides
- Choose appropriate and approved agrochemicals
- Provide protective equipment and clothing and ensure its use

Risks to Collection
- Risk management plan includes mitigation and response contingencies for all potential risks to the physical collection
13. Infrastructure and equipment

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 screenhouse for keeping certain accessions that are difficult to maintain in the field under more controlled conditions is often desirable. The 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

<table>
<thead>
<tr>
<th>General needs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acquisition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
<td></td>
</tr>
<tr>
<td>Data collection sheets or mobile devices for electronic data recording, GPS or altimeter</td>
<td></td>
</tr>
<tr>
<td>Incinerator, surface decontamination solutions, knives, forceps, scalpels, balance for weighing fruit and seeds, camera for recording samples on arrival</td>
<td></td>
</tr>
<tr>
<td>Field establishment and management</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regeneration and propagation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse or field space for growing cuttings, pots, compost, rootstock, rooting media</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characterization and evaluation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to field, lab or greenhouse areas as required</td>
<td></td>
</tr>
<tr>
<td>Field/lab/greenhouse equipment and machinery, as necessary, according to species and traits being recorded</td>
<td></td>
</tr>
<tr>
<td>Pots and plot stakes and labels (ideally barcoded labels), labelled cloth bags or other appropriate containers</td>
<td></td>
</tr>
<tr>
<td>Molecular analysis (RAPD, ISSR, SSR) equipment, if possible.</td>
<td></td>
</tr>
<tr>
<td>Data sheets or mobile devices for electronic data recording, barcode reader</td>
<td></td>
</tr>
</tbody>
</table>

**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 viability and flag accessions requiring regeneration. |
| 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. 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.\textsuperscript{228}

General references


Acquisition and distribution


Establishment of field collections and field management


Regeneration and propagation


Characterization and evaluation


Molecular characterization and evaluation


Documentation


Safety duplication


Nordgen. 2008. Agreement between (depositor) and the Royal Norwegian Ministry of Agriculture and Food concerning the deposit of seeds in the Svalbard Global Seed Vault. The Svalbard Global Seed Vault.

Infrastructure and equipment


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

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| Loss of adaptive alleles due to selection pressures                  | • Choose a site with agro-ecological conditions as similar as possible to the environment where the collected plant materials originated  
  • Choose a location that minimizes risks from natural and manmade 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                                      |
| 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   | • 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 |
|                                                                   | species that are used to produce seeds for distribution.                                                                                                  |

Acquisition

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity of the source population is not adequately represented in</td>
<td>• Develop and follow agreed collecting strategy and methodology that adequately follow genetic sampling guidelines</td>
</tr>
<tr>
<td>the collected sample</td>
<td></td>
</tr>
</tbody>
</table>
| Taxonomic misidentification                                          | • Include a taxonomist in 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**

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

**Regeneration and propagation**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of adaptive alleles due to selection pressures</td>
<td>- Follow appropriate cultural practices</td>
</tr>
<tr>
<td></td>
<td>- Regenerate at sites with a similar climate to that of the collection site where the material originated</td>
</tr>
<tr>
<td></td>
<td>- Outsource regeneration if necessary</td>
</tr>
<tr>
<td>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)</td>
<td>- Follow recommended crop-specific isolation distances or use isolation cages, bagging or other pollination-control measures</td>
</tr>
<tr>
<td>Poor levels of pollination (for outcrossing species that are used to produce seeds for distribution)</td>
<td>- Use pollination cages to enclose insect pollinators.</td>
</tr>
<tr>
<td></td>
<td>- Ensure adequate availability of insect pollinators</td>
</tr>
<tr>
<td></td>
<td>- Hand pollinate as required/where possible</td>
</tr>
</tbody>
</table>
Misidentification of sample

- Check plot and bag labels prior to planting and harvesting; use barcode labels

Characterization and evaluation

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| 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 sample   | • Use check accessions/varieties (for vegetatively propagated annuals)  
|                               | • Check plot labels while collecting data  
|                               | • Check plot and bag labels prior to sowing and harvesting |
| Misidentification of sample   | • Use check accessions/varieties  
|                               | • Check plot labels while collecting data  
|                               | • Check plot and bag labels prior to sowing and harvesting |

Distribution and safety duplication

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| 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. |
ANNEX 3. Draft Practical Guide for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture

Conservation of PGRFA via *In Vitro* Culture

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1. Introduction

Many field and horticultural crops as well as agroforestry species are difficult or impossible to preserve as seeds. These include: species that only produce recalcitrant seeds with a short life span in seed storage; species for which seed production may take many years, as is the case for many tree species: species that are heterozygous and therefore do not produce true-to-types seeds; and species that do not produce seed at all and are vegetatively propagated. Other examples include males of dioecious species and rare plants that are under threat of overgrazing and for which time to produce seeds before the population totally vanishes is limited. *In vitro* conservation offers an option for these species. Additionally, *in vitro* techniques provide a germplasm storage procedure that combines the possibility of disease elimination with that of rapid clonal propagation, thus providing a means by which germplasm can be safely exchanged and distributed.

*In vitro* slow growth storage techniques are being routinely used for medium-term conservation of numerous species of both temperate and tropical origin, including crop plants (e.g. potato, yam and cassava), and rare and endangered species. Germplasm can be stored for between several months and 2–3 years without subculture, depending on the technique used and the genotype of the plant material.

*In vitro* 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.229

Conservation in genebanks by means of *in vitro* culture can be broken down into a series of interrelated operations (Figure 1). This practical guide for conservation in genebanks by means of *in vitro* culture presents practices and activities230 critical to each operational area (Table 1). It outlines workflows for routine genebank operations for the conservation via *in vitro* culture (Figure 2), and supports the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture (Genebank Standards).231 The purpose of this guide is to present the information contained in the Genebank Standards in a format that details the actions of the genebank workflow in a sequential manner and thereby facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis for the development of Standard Operating Procedures (SOPs)232 and Quality Management Systems233 for conserving these 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 genebank for *in vitro* culture. Each genebank will have its own 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, genebank staff will need to consult various sources of information, a few of which are referenced in this booklet.

230 Practices and activities follow best practices as outlined in the Genebank Standards.
233 https://www.genebanks.org/the-platform/quality-management/
Figure 1. Major operations for conservation via *in vitro* culture
Table 1: The underlying principles and related genebank operations for *in vitro* genebanks

<table>
<thead>
<tr>
<th>Genebank principle</th>
<th>Summarized genebank operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identity of accessions</td>
<td>Passport data collected and recorded</td>
</tr>
<tr>
<td></td>
<td>Botanical identity verified</td>
</tr>
<tr>
<td></td>
<td>Permanent and unique accession number assigned and used in all documentation</td>
</tr>
<tr>
<td></td>
<td>Accessions handled carefully to avoid mixing, and all samples labelled and tracked through genebank operations and in the laboratory, field and greenhouse</td>
</tr>
<tr>
<td>Maintenance of viability</td>
<td>Best practices followed and timing optimized during collection, processing, introduction into <em>in vitro</em> culture and slow-growth storage, regeneration and transportation</td>
</tr>
<tr>
<td></td>
<td><em>In vitro</em> culture and slow-growth storage conditions optimized and monitored</td>
</tr>
<tr>
<td></td>
<td>Germplasm health monitored regularly</td>
</tr>
<tr>
<td></td>
<td>Regeneration undertaken when necessary</td>
</tr>
<tr>
<td>Maintenance of genetic integrity</td>
<td>Collection and maintenance of samples conducted in a manner that ensures they represent the original population as much as possible</td>
</tr>
<tr>
<td></td>
<td>Best practices followed during packaging, introduction into <em>in vitro</em> culture and slow-growth storage and regeneration</td>
</tr>
<tr>
<td></td>
<td>Genetic stability evaluated</td>
</tr>
<tr>
<td>Maintenance of germplasm health</td>
<td>Quarantine procedures undertaken when needed</td>
</tr>
<tr>
<td></td>
<td>Best practices followed during collection, processing, introduction into <em>in vitro</em> culture and slow-growth storage, regeneration and transportation</td>
</tr>
<tr>
<td></td>
<td>Contamination monitored and managed in the laboratory and in the field or greenhouse.</td>
</tr>
<tr>
<td>Physical security of collections</td>
<td>Risk management strategy developed and implemented</td>
</tr>
<tr>
<td></td>
<td>Accessions safety duplicated/safety backed-up</td>
</tr>
<tr>
<td></td>
<td>Appropriate genebank infrastructure in place and maintained</td>
</tr>
<tr>
<td>Availability and use of germplasm</td>
<td>Germplasm acquired and distributed according to legal and phytosanitary requirements</td>
</tr>
<tr>
<td></td>
<td>Sufficient stocks and efficient and timely dispatch of samples ensured</td>
</tr>
<tr>
<td></td>
<td>Relevant documentation provided to recipients of genebank material</td>
</tr>
<tr>
<td>Availability of information</td>
<td>Genebank information management system in place</td>
</tr>
<tr>
<td></td>
<td>Passport and accession-management data secured by regular data backups</td>
</tr>
<tr>
<td></td>
<td>Passport and other relevant data available and accessible to external users, as far as possible</td>
</tr>
<tr>
<td>Proactive management of genebanks</td>
<td>Standard operating procedures developed and available to staff</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Data and information generated during genebank activities available to managers and staff</td>
</tr>
<tr>
<td></td>
<td>Well-trained staff employed and protected by occupational safety and health measures</td>
</tr>
<tr>
<td></td>
<td>Genebank staff capacities kept up to date and training provided as necessary</td>
</tr>
</tbody>
</table>
Figure 2. Flow of germplasm in a genebank for *in vitro* conservation. Each step is associated with proper documentation.
2. Acquisition of germplasm

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

- **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.\(^{234}\)
  
  - 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.\(^{235}\)**
  
The process of germplasm acquisition is governed by national and international regulations.
  
  - The genebank should communicate with National Focal Points for the International Treaty on Plant Genetic Resources for Food and Agriculture (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)\(^{236}\) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remain with all material derived from the accession during all genebank handling (viability testing, storage, regeneration and distribution).
  
  - 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.\(^{237}\)**
  
  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 (MCPD v.2.1).\(^ {238}\)


\(^{235}\) See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf


\(^{237}\) See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf

\(^{238}\) https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
• The associations 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.

1.1. 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:
   • emphasize the importance of conducting inventories and gap analyses in order 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 to ensure best practices and compliance with regulations and requirements.

✓ Collected germplasm is legally acquired and accompanied by all relevant documentation.239
   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.
     o 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.
     o 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) 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.241

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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; \(^{(242)}\)
- passing samples through the relevant quarantine process before they are transferred to the genebank, if required; and
- processing collected materials in containment or in an isolated area, according to the advice of the national phytosanitary authority.

✓ 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. \(^{(243)}\)

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, whether vegetative or recalcitrant seeds (or their fruits). Collecting late-season recalcitrant seeds of any species should be avoided. Whole fruits of uniform maturity status should be collected from the parent plants prior, but as close as possible, to natural abscission. Avoid collecting fallen fruits from the ground, especially those showing damage or signs of weathering. Seasonality is a consideration for the collecting of bulbs, tubers and woody species.

✓ Propagules/explants are collected from an appropriate number of individual plants, \(^{(244)}\) but the depletion of the natural population targeted for collecting is avoided.

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. \(^{(245)}\)

- It is recommended to harvest from at least 30 individuals for cross-fertilizing species and 60 individuals for autogamous species, if possible.
  - For roots and tubers, collect a minimum of four propagules for each sample, more if culturing techniques for that species are not reliable. \(^{(246)}\)
  - 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. \(^{(247)}\)
- 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 (w/v) calcium hypochlorite, may also be used. After decontamination,

\(^{(242)}\) There are 183 contracting parties to the International Plant Protection Convention and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/nppos/list-countries/


\(^{(244)}\) See Genebank Standards (Standard 6.1.3): http://www.fao.org/3/a-i3704e.pdf

\(^{(245)}\) The Crop Genebank Knowledge Base provides very useful information on collecting: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

\(^{(246)}\) https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=666

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.

✓ **Collected samples are labelled and are not mixed during handling.**
Use indelible ink or computer-generated labels (preferably with barcodes), if possible, on the
sample 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.

✓ **The period between collecting and processing and then transferring to the genebank is as
short as possible to prevent loss and deterioration of the material.**
Recalcitrant seeds are sensitive to desiccation and chilling injury. Water loss curtails storage life
span. Similarly, 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) should be taken into account in order to ensure that the material reaches the
destination genebank in good condition. The following considerations may decrease the risk of
germplasm loss after collecting missions:

**Packaging**

- Precautions should be taken to avoid risk of fungal or insect attacks during shipment.
  - If a pest has been observed and correctly identified, it may be necessary to apply
    pesticide before packaging. Avoid any unnecessary chemical treatment, as it may
    be harmful to the collected samples. If applied, declare treatments 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 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 (in the case of fleshy fruits).

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250 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.
• 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.

**Transport**

• For long transit times by road, periodic aeration of the collected material may be necessary as a precaution against viability lost.
• Sending shipments by the fastest means possible, either by airfreight or by courier, should avoid deterioration of sample quality and long exposure to adverse environmental conditions.
• Continuous tracking of the package, if possible, will ensure genebank staff are prepared to process the samples upon their arrival at the genebank. Note that 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 and processed in a way that does not alter the physiological status .

• 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 micro-organisms, taking into account any decontamination treatment given prior to packaging and transport.
• Quarantine measures are applied as necessary.

 ✓ Collected germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.

A standardized form for collecting the associated data for each sample obtained is helpful. Each sample is assigned a collection number so the samples can be linked to the collected information. Collecting the following information may be considered:

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251 See Genebank Standards (Standard 6.1.5): http://www.fao.org/3/a-i3704e.pdf

• 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 (MCPD v.2.1) (Box 1); 253
• Information on origin of the germplasm, traditional knowledge, cultural practices, etc., if collecting from farmers’ fields/stores; and
• 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.

2.3 Germplasm acquired through transfer/donation

✓ Donated germplasm is legally acquired and accompanied by all relevant documentation. 254
• 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, 255 it is necessary to use a Standard Material Transfer Agreement (SMTA). 256
• 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, 257,258 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.

✓ Donated germplasm is accompanied by the associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors. 259

It is recommended to request donors that samples be accompanied by the associated data detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v.2.1). 260-261

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255 http://www.fao.org/3/a-bc084e.pdf
256 https://mls.planttreaty.org/itt/
257 An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.
261 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;\(^\text{262}\)
- passing samples through the relevant quarantine process before they are transferred to the genebank, if required; and
- processing 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 and processed in a way that does not alter the physiological status.\(^\text{263}\)

- 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 micro-organisms, taking into account any decontamination treatment given prior to packaging and transport.
- Quarantine measures are applied as necessary.

\(^{262}\) There are 183 contracting parties to the International Plant Protection Convention, and a list of National Plant Protection Organizations can be retrieved at the following site: https://www.ippc.int/en/countries/nppos/list-countries/

\(^{263}\) See Genebank Standards (Standard 6.1.5): http://www.fao.org/3/a-i3704e.pdf
Figure 3. Summary diagram for acquisition of germplasm
3. *In vitro* culture and slow-growth storage

The genebank should have a documented policy and/or procedure, as applicable, for *in vitro* culture and slow-growth storage, including guidelines and methodologies for explant identification, initiation into *in vitro* culture, recycling/rejuvenation, media composition, and both light and temperature regimes.

**A. In vitro culture**

✓ **The culture media composition for initiating the explant *in vitro* and for multiplication is determined according to the species.**

It may be necessary to carry out a literature review to investigate whether conditions for *in vitro* culture have been established for the target genotype or any related species. In most cases, modifications to published techniques will be required or new techniques developed for taxa not cited in the literature.

✓ **The appropriate type of explant and the optimum time (growth stage and physiological age of parent plant) for initiation into culture is determined for a particular genus or species from the literature or by experimentation.**

There are various types of explants frequently used for initiation into culture: nodal segments, apical meristems, roots, cotyledons, embryos, leaf discs, leaf blades, pedicles, petioles, anther, ovaries, etc.

✓ **Explants are free from known diseases and microbial contaminants.**

To ensure viable and disease-free establishment, the following practices should be considered:

- obtaining explants from vigorous and healthy mother plants.
- indexing mother plants to determine the presence/absence 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.264
- applying surface decontamination methods to eliminate contaminants from explants excised from field-grown or greenhouse-grown material (*ex vivo*);
  - Examples include sterilizing using bleach solution, hot water treatment and treatment with ozone dissolved in water.265
- transferring explants to a rich detection medium, which favours micro-organism growth and therefore allows for early determination of contamination, and treatment or elimination of contaminated cultures;266 and
- if necessary, regenerating *in vitro* plantlets from virus-infected plants and using various chemical or thermotherapy techniques267 to produce virus-free material before long-term conservation.

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265 See: Umber et al. https://doi.org/10.3390/v12101101
Once successfully initiated into culture, the accession is multiplied for either normal growth (active growing conditions) or slow growth storage. In vitro cultures serve as sources of disease-free materials for distribution and multiplication and as a source of explants for cryopreservation. Regular monitoring, and safe removal and disposal of infected materials, is essential.

Rapid propagation of selected materials is necessary for research or distribution. It is important to note that the multiplication rate strongly depends on the genotype of the accession and is influenced by the composition of the medium (particularly the cytokinin concentration), the explant size, age of culture and the size of the culture vial. 268

Any cultures exhibiting somaclonal variation are discarded. Somaclonal variation is the result genetic or epigenetic changes that arise in vitro among clonal regenerates and their corresponding donor plants. 269 The occurrence of somaclonal variation during in vitro culture has a negative effect on the rapid production of clonal plants for distribution and cultures in which this has happened must be discarded.

Culture containers are clearly labelled following genebank practice. 270

B. Slow-growth storage

Slow-growth storage conditions are optimized for the target species. 271 It may be necessary to carry out a literature review to investigate whether conditions for slow-growth storage conditions have been established for the target species or genotype, or any related species. If this information is not available, then conditions will have to be established by experiment. Standard protocols have been published and can be used for guidance. 272 Slow-growth storage conditions can include:

- Physical growth limitation, including: (a) low temperature; (b) low light/restricted photoperiod; (c) minimal containment; (d) minimal O2; and (e) osmotic (water) stress.
- Chemical growth limitation, including: (a) growth regulator retardation and (b) growth inhibitors.
- Nutrient limitation, including: (a) low macronutrient levels; and (b) low micronutrients levels.
- Avoidance of the formation of callus and other abnormalities, such as hyperhydration, and somaclonal variation.
  - Material for in vitro conservation maintained as whole plantlets or shoots 273 can avoid hyperydricty.
  - Techniques for avoiding hyperhydration include culturing on medium containing 6-bensyladenine (BA), kinetin (Kin) or thidiazuron (TDZ), 274 and modifying the ratio of NH4+/NO3-. 275

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270 Information on labels could include accession number, date of introduction and line number (number of cuttings from the accession).
272 See Further Information/Reading section.
Avoiding the excess use of growth regulators in media can reduce the possibility of later callus formation in storage and thus minimize the risk of somaclonal variation. Avoiding too many subcultures can also decrease the risk of somaclonal variation.

The optimum storage conditions are selected by visually assessing the general performance of each culture using the following criteria: vigour, fungal and bacterial contamination, chlorosis, blackening, tissue necrosis, hyperhydration and etiolation.

Optimum storage conditions are minimal growth conditions that prove to be acceptable for most genotypes. Not all accessions and genotypes will respond equally well to the applied conditions. For cold-tolerant species, storage conditions often range from 0 to 5 °C; the lowest temperatures tolerated by many tropical species often range from 15 to 20 °C.276

Germplasm for storage is selected from young cultures that have not been subject to too many subcultures in order to minimize the chance of selecting a variant plant.

As the storage capacity of in vitro cultures strongly depends on the initial quality of the cultures, the following practices are encouraged:

- visually assessing the general performance of each culture using the following criteria prior to selection for slow growth storage: vigour and absence of fungal and bacterial contamination; chlorosis, blackening or tissue necrosis;
- discarding contaminated and low-quality cultures immediately; and
- propagating cultures onto a new medium if all cultures under evaluation have been found to be below standard because at least one of the above criteria is not met.

The number of replicates to put into storage is determined. It is important to maintain a sufficient number of replicates per accession to ensure that genetic integrity is maintained,277 taking into account: (a) cost; (b) potential risks (the greater the risks, the larger the sample size); (c) the duration between subculture periods and how the slow-growth conditions affect the propagation potential (number of shoots/nodes available for multiplication after storage); and (d) the purpose of the collection (active or base). If an accession only produces a few plants per subculture and is used for active distribution, more replicates will be required than if the accession is solely in a backup collection.

Culture containers are clearly labelled following genebank practice.278

Regular monitoring is carried out to detect and remove those in vitro cultures that exhibit any variation from whole plantlets, including somaclonal variation, contamination, and hyperhydration, etc.279

All in vitro culture and slow-growth storage data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.

Data to consider include: type of explant; explanting/culture initiation date; initiation/establishment medium; multiplication medium; rooting medium; slow-growth storage medium; number of replicates for slow-growth storage; performance indicators for in vitro culture and slow-growth storage; number of subcultures and duration of subculture period; and any specific growth characteristics, such as callus formation during storage and tendency to

277 This will vary depending on species.
278 Information on labels could include accession number, date of introduction and line number (if applicable).
become hyperhydrated. 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.

Figure 4. Summary diagram for *in vitro* culture and slow-growth storage of germplasm
4. Recycling and rejuvenation

The genebank should have a documented policy and/or procedure, as applicable, for recycling and rejuvenation, including guidelines and methodologies for monitoring, subculturing, acclimatization and transfer to the field.

Reycling:

✓ **Subculturing is carried out at the end of the storage cycle, when accessions show obvious signs of deterioration and/or when stock becomes low and there is a need for multiplication or safety duplication.**

Accessions should be regularly monitored for signs of necrosis. At the end of a storage cycle, new cultures are best placed for a short period under optimal conditions to encourage regrowth before the start of the next storage cycle. For security of collections, it is prudent to maintain a few viable and healthy cultures of the previous subculture cycle as “spare materials” until the newly subcultured set is healthy and growing.

✓ **Genetic stability is periodically assessed by means of visual assessment and transfer to the field for morphological observations or by using cytological or molecular techniques.**

It is important to develop a system for monitoring quality, viability, stability and contamination. Once the material has been in storage for a given time, quantitative and qualitative monitoring criteria should be used to assess the viability of an accession and to identify when it should be subcultured.

Rejuvenation:

✓ **Those cultures requiring rejuvenation (transfer of accessions to the greenhouse and field, followed by reinitiation into tissue culture) is determined.**

Cultures that are too old and have gone through too many cycles of recycling are rejuvenated. The timing of when rejuvenation is required will depend on the genotype and the in vitro conditions.

- Often, a threshold value is established based on experimentation (or is known from the literature). A threshold value is the number of cultures for a given genotype at which experiments have shown vigour declines and/or cultures become too old.
- If the number of cultures reaches this threshold, the accession should be transferred to the greenhouse or field for rejuvenation and reinitiation into tissue culture.

✓ **In the case of contamination of all replicates, material is subjected to rejuvenation and/or a decontamination treatment.**

Surface-decontaminated can be carried out 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 (w/v) calcium hypochlorite, can also be used.

✓ **Selected germplasm undergoes an acclimatization process prior to transfer to the greenhouse or field.**

The progressive change of environment before the transfer to field conditions is called acclimatization or hardening, and includes first planting pots in a greenhouse environment. A number of practices are recommended, including:

- selecting plantlets showing a well-developed root and shoot systems for acclimatization;
- removing any media from roots before planting in pots; and
• using sterile soil or planting medium.

✓ **Appropriate field management and cultural practices are applied.**

✓ **Optimal procedures are used to minimize risk to the genetic integrity of the accession.**

Accessions with the same characteristics as the original genotype are considered true-to-type. Assess trueness-to-type by comparing morphological and taxonomic characteristics of the plants with those of the original accession. Ideally, accessions are grown in a field collection next to the original mother plant.

• True-to-type accessions can be re-established in *in vitro* culture.

• Accessions identified as off-types with no value, or accessions that are found to be mislabelled, must be discarded and replaced with the original true-to-type material from the donor source.

• **Note:** Using field established plants to rejuvenate the accession in storage would require re-indexation for viruses, as the plants could have been exposed to them.

✓ **All recycling and rejuvenation data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**

Data to consider include inventory, date of subculture, date of initiating acclimatization, planting date, greenhouse and field cultural practices used, date of reinitiating into culture, 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 5. Summary diagram for recycling and rejuvenation of germplasm

- Subculture accessions at the end of the storage cycle or when there is a need for multiplication or safety duplication
- Recycle when Inventory below threshold
- Recycle when obvious signs of deterioration or if genetic stability is in question

- Appropriate and species-specific *in vitro* culture techniques (culture media, type of explant, time for initiation into culture, explants free from known diseases and contaminants)

- Rejuvenate cultures that are too old and have gone through too many cycles of recycling
- Rejuvenate in the case that all replicates show contamination

- Acclimatize germplasm prior to transfer to the greenhouse or field
- Appropriate field management and cultural practices

- Use field maps
- Clearly label culture vessels or greenhouse pots
- verify trueness-to-type in the field
- Use isolation measures as needed

Record, validate and upload all recycling and rejuvenation data and images
5. Characterization and evaluation

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

- **Characterization and evaluation data are obtained for as many accessions as possible and as soon as possible.**
  
  It is essential that staff be well trained in data recording, evaluation techniques carried out *in vitro* and field work.

- **Characterization and evaluation of most traits are carried out when accessions are taken out of *in vitro* conditions.**
  
  Taking accessions out of *in vitro* conditions provides an opportunity for characterization and evaluation data to be generated in the greenhouse or field.

- **Evaluation is carried out under *in vitro* conditions for certain easily screened traits, such as salt and drought tolerance.**
  
  The correlation between evaluation data from *in vitro* and field conditions should be established first.

- **Germplasm is characterized for a set of highly heritable morphological traits to describe, and species-specific characterization procedures are based upon standardized and calibrated measuring formats and categories, following internationally agreed descriptor lists as much as possible.**
  
  The use of standardized crop descriptor lists and calibrated and standardized measuring formats enable the comparison of data across institutions and countries. A wide range of crop descriptor lists has been developed (for example by Bioversity International,280 The International Union for the Protection of New Varieties of Plants(UPOV),281 and the National Plant Germplasm System (NPGS) of the United States).282 If there are no existing descriptor lists for a species, it is recommended to use Bioversity International’s Guidelines for Developing Crop Descriptor Lists.283

- **Evaluation data are presented using appropriate methods.**
  
  The use of standardized crop descriptor lists and calibrated and standardized measuring formats enables the comparison of data across institutions and countries. 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.

- **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 help identify mislabelled plants and duplications. 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

280 [https://www.bioversityinternational.org/e-library/publications(descriptor)](https://www.bioversityinternational.org/e-library/publications/descriptors/)

281 [https://www.upov.int/test_guidelines/en/](https://www.upov.int/test_guidelines/en/)

282 [https://www.ars-grin.gov/npgs/cgclist.html](https://www.ars-grin.gov/npgs/cgclist.html)

283 Bioversity International. 2007. *Guidelines for the development of crop descriptor lists*. Bioversity Technical Bulletin Series. Rome. (available at: [https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=1053&cHash=39138e10e405def0f918c6670c877b4f](https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=1053&cHash=39138e10e405def0f918c6670c877b4f)).
marker technologies include DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.\textsuperscript{284} Molecular characterization may be outsourced to specialized laboratories.

- All characterization and evaluation data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.
  Data to consider include descriptor measured and results, date recorded, staff responsible, laboratory techniques (molecular, etc.) and dates carried out. 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 and evaluation data are made publicly available.
  Making selected data publicly available to potential germplasm users at genebank, country, regional and global levels will serve to enhance germplasm use (see Documentation). The publishing of characterization and evaluation data is therefore highly recommended.

\textsuperscript{284} A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.
Figure 6. Summary diagram for characterization and evaluation of germplasm
6. Documentation

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

- **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 (MCPD v.2.1)\(^{285}\) and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation\(^{286}\) facilitate data exchange and comparison of accessions across different countries and institutions. Passport data are ideally available for all accessions in the genebank collection.\(^{287}\)

  A unique and permanent accession number is a key element of proper documentation and identification. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)\(^{288}\) 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.

- **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 in vitro conservation and use of germplasm, including passport, and in vitro culture and slow-growth storage, regeneration, characterization, evaluation and management data and metadata. Built-in automated tools for checking inventory and viability, and flagging accessions requiring regeneration, should be available.

  GRIN-Global has been developed by USDA-ARS, the Crop Trust and Bioversity International to enable genebanks to store and manage information associated with plant genetic resources, and is freely available.\(^{289}\) Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),\(^{290}\) the German Genebank Information System (GBIS)\(^{291}\) and Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa).\(^{292}\)

- **Data are publicly available in a search-query database, if possible.**
  
  Publishing data on genebank holdings increases the 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.\(^{293}\) Genesys allows sharing accession data from genebanks around the world, and facilitates the ordering of germplasm. It includes accession-level passport, characterization and evaluation data as well as environmental information associated with accession collecting

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\(^{286}\) See Regeneration, Characterization and Evaluation sections.


\(^{289}\) [https://www.grin-global.org/](https://www.grin-global.org/)

\(^{290}\) [http://seed.worldveg.org](http://seed.worldveg.org)


\(^{292}\) [http://alelo.cenargen.embrapa.br/alelo_en.html](http://alelo.cenargen.embrapa.br/alelo_en.html)

\(^{293}\) [https://www.genesys-pgr.org/welcome](https://www.genesys-pgr.org/welcome)
sites. Another option for making 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).\(^{294}\) By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals,\(^{295}\) WIEWS stores and publishes accession-level passport data for the largest global inventory of \textit{ex situ} collections.\(^{296}\)

- **All data and information generated relating to all aspects of conservation and use of germplasm, including images and metadata, are validated and uploaded to the genebank information management system.**\(^{297}\)
  
  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.

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

\(^{294}\) http://www.fao.org/wiews/en/

\(^{295}\) https://unstats.un.org/sdgs/metadata?Text=&Goal=2&Target=2.5


\(^{297}\) See Genebank Standards (Standard 6.6.3): http://www.fao.org/3/a-i3704e.pdf
Figure 7. Summary diagram for documentation
7. Distribution

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 authority, as necessary.

✓ The genebank complies with national, regional and international regulations and agreements.²⁹⁸

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 Treaty²⁹⁹ is being distributed for the established intended uses (i.e. research, breeding and training for food and agriculture), it is necessary to use a Standard Material Transfer Agreement (SMTA).³⁰⁰
- 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 to come to an agreement with the recipient on the terms and conditions of germplasm distribution, usually through a Material Transfer Agreement (MTA).³⁰¹,³⁰²

✓ A policy is in place for the number of plantlets to distribute for any given species.

The average size of sample distributed by in vitro genebanks is approximately 3–5 plantlets per accession. For accessions with too few plantlets 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 plantlets is sufficient.

✓ The capacity of the recipient to adequately manage in vitro material is assessed, if possible.

Ensuring that the distributed germplasm sample will be efficiently used is an important step in managing resources. Often a simple questionnaire form will provide the information needed to assess this.

✓ The distributed germplasm is of high quality.

It may be necessary to subject material to rejuvenation and/or a decontamination treatment if all replicates are contaminated.

✓ Conditions for the transfer of material are established between the genebank and the recipient and adequate means of re-establishing plants from in vitro culture are confirmed.³⁰³

²⁹⁹ http://www.fao.org/3/a-bc084e.pdf
³⁰⁰ https://mls.planttreaty.org/itt/
³⁰¹ An example of an MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively, an SMTA can be used or adapted.
³⁰³ See Genebank Standards (Standard 6.7.3): http://www.fao.org/3/a-i3704e.pdf
Recipients should have the means to transfer the materials either to pots or to the field. Alternatively, arrangements should be made with other institutes to ensure successful transfer. Genebanks can share information on handling germplasm with recipients to facilitate use.

- **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.

- **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.**
  Samples should be correctly labelled, preferably with computer-produced labels to reduce transcription errors. Labels should be placed both outside and inside each seed packet to ensure that the material is properly identified.

- **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.**
  Consider scanning documents and sending them by e-mail, or sending hard copies by mail, prior to the dispatch of the germplasm. Documentation to consider include:
  - data on accessions (including an itemized list with accession identification, seed lot/generation identification, number and/or weights of samples, and key passport data); and
  - import permit, phytosanitary certificate, or customs declaration, if appropriate.

- **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). *In vitro* samples should be placed in sterile, leak-proof plastic bags or sterile transparent watertight sealed plastic vials 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.

- **The delivery and condition of the germplasm on arrival at its destination is followed up to confirm that germplasm has reached the recipient sufficiently quickly.**
  It is suggested that shipments be tracked and that the genebank follow up with the recipient regarding the status and usefulness of the distributed germplasm.

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

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Data to consider include: requester’s name and address, purpose of request and request date; samples requested, samples sent and number of plantlets per sample; reference to phytosanitary certificate and SMTA\textsuperscript{305} or MTA\textsuperscript{306} 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.

\textsuperscript{305} https://mls.planttreaty.org/itt/
Figure 8. Summary diagram for distribution and exchange of germplasm
8. Safety duplication

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.307

✓ 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.308

Safety duplicates are deposited at a 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 vitro309 conditions for the duplicated accessions. Alternatively, samples can be cryopreserved at the duplicating centre.310 Selection of, and clear agreement with, the chosen holder of the safety duplicate are critical.

✓ A legal agreement setting out the responsibilities of the depositing and the recipient genebanks, 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 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;
• subjecting material to rejuvenation and/or a decontamination treatment if required; and
• ensuring that the size of safety-duplicated samples is sufficient to avoid risk of loss.311

✓ 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.

307 Duplicated material includes plants to be managed in the field, plantlets maintained in vitro or meristematic tissues under cryopreservation.
308 See Genebank Standards (Standard 5.10.4): http://www.fao.org/3/a-i3704e.pdf
310 See Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf
311 It is recommended to duplicate a minimum of three to five replicates/samples per in vitro accession
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.\(^{312}\)

It is recommended that relevant information be sent with the shipment, including an itemized list with accession identification, key passport data, total quantity of seeds (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.

✓ All safety duplication data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.

Data to consider include: the location of the safety-duplicated accessions, samples sent and number of replicates/plantlets per sample; indexing method, if applicable; shipping log and user feedback; 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.

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\(^{312}\) See Genebank Standards (Standard 6.8.5): http://www.fao.org/3/a-i3704e.pdf
Figure 9. Flow diagram for safety duplication of germplasm

- Consider issues like biosecurity, geopolitical situation, likelihood of natural disasters, cost.
- Ensure hosting genebank/institute has good management capabilities to provide appropriate conditions for maintaining the duplicated germplasm (in vitro or cryopreservation)

- Request information from host genebank the required documentation (both for the genebank and the host country), and the applicable customs and quarantine procedures

- Subject material to rejuvenation and/or a decontamination treatment in the case of contamination of all replicates

- Use computer-produced labels to reduce transcription errors, place labels both outside and inside each packet

- Use packing and shipping protocols similar to those for distribution

- Include accession data (accession identification, number of samples, and key passport data), import permit, phytosanitary certificate and/or customs declaration
- Send scanned documents in advance by email to the recipient

Record, validate and upload all safety duplication data
9. Personnel and security

**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.

- **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. 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;
  - 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 every-day environment to which the 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. 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:

  - *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;

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• **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; and
• **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.

✔ **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. Most countries will have an OSH policy. The International Labour Organization (ILO) 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 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.

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Figure 10. Summary diagram for personnel and security
10. Infrastructure and equipment

This section considers the suggested infrastructure and equipment for an *in vitro* genebank (Table 2). *In vitro* genebanks are generally equipped with: (a) basic tissue culture equipment, growth rooms and support facilities; (b) specialist storage equipment, such as incubators and acclimatizing chambers; (c) microscopes and analytical and molecular equipment for germplasm authentication and performance and stability testing; and (d) safety equipment, such as alarms and smoke detectors.

Factors that should be considered if designing or modifying genebank facilities include: (a) function of the facility (active collections, research and long-term storage); (b) projected throughput and number of accessions for storage; (c) expected distribution rates; (d) local climate, of particular importance in the tropics because of potential contamination issues; and (e) number of staff.

References are available for setting up and running *in vitro* facilities, 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 an *in vitro* genebank**

<table>
<thead>
<tr>
<th>Genebank operation/management area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General needs</strong></td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td><strong>Acquisition</strong></td>
</tr>
<tr>
<td>Collecting equipment including cloth and/or paper bags, moisture retaining bags/containers, labels (ideally barcoded labels), hand lenses, scissors, tarpaulins, secateurs, packaging materials, herbarium presses</td>
</tr>
<tr>
<td>Data collection sheets or mobile devices for electronic data recording, GPS or altimeter</td>
</tr>
<tr>
<td>Incinerator, surface decontamination solutions, knives, forceps, scalpels, balance for weighing fruit and seeds, camera for recording sample on arrival</td>
</tr>
<tr>
<td><strong>In vitro culture and slow growth storage</strong></td>
</tr>
<tr>
<td>Autoclave, pH meter, balance, water distillation unit, magnetic stirrer, water bath, automatic pipettes, glassware, chemicals, laminar airflow cabinets, beads sterilizer or burner, fridge/freezer, stereo dissecting microscopes, dissecting instruments, culture medium components, different, culture containers, slow growth media components, temperature controlled growth rooms, growth room shelving and lights, media for screening for contaminants, antibiotics, fungicides</td>
</tr>
<tr>
<td><strong>Recycling and rejuvenation</strong></td>
</tr>
<tr>
<td>Greenhouse and/or field environment for growing out <em>in vitro</em> plants to assess changes in morphology, pots, compost.</td>
</tr>
<tr>
<td><strong>Characterization and evaluation</strong></td>
</tr>
<tr>
<td>Access to field, lab or greenhouse areas as required</td>
</tr>
<tr>
<td>Field/lab/greenhouse equipment and machinery, as necessary, according to species and traits being recorded</td>
</tr>
<tr>
<td>Category</td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td><strong>Pots and plot stakes and labels</strong></td>
</tr>
<tr>
<td>Molecular analysis (RAPD, ISSR, SSR) equipment</td>
</tr>
<tr>
<td><strong>Documentation</strong></td>
</tr>
<tr>
<td>Data backup/storage</td>
</tr>
<tr>
<td><strong>Distribution and safety duplication</strong></td>
</tr>
<tr>
<td>Data sheets or mobile devices for electronic data recording, barcode reader</td>
</tr>
<tr>
<td><strong>Security and personnel</strong></td>
</tr>
<tr>
<td>Protective clothing and protective gear</td>
</tr>
</tbody>
</table>
11. Further information/reading

General references


**SGRP-CGIAR (System-wide Genetic Resources Programme of the Consultative Group on International Agricultural Research).** Crop Genebank Knowledge Base. https://crogenebank.sgrp.cgiar.org/

Acquisition and distribution


**In vitro culture and slow-growth storage**


http://hdl.handle.net/10568/66354


### Recycling and rejuvenation


Characterization and evaluation


Molecular characterization and evaluation


Documentation


Safety duplication

**Nordgen.** 2008. Agreement between (depositor) and the Royal Norwegian Ministry of Agriculture and Food concerning the deposit of seeds in the Svalbard Global Seed Vault. The Svalbard Global Seed Vault.

**Infrastructure and equipment**


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.

**Acquisition**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity of the source population is not adequately represented in the collected sample</td>
<td>• Develop and follow an agreed collecting strategy and methodology that adequately follows genetic sampling guidelines</td>
</tr>
</tbody>
</table>
| Taxonomic misidentification                                          | • Include a taxonomist in the collecting team and hire genebank staff trained in taxonomy  
  • Take herbarium vouchers and photos for verification by experts           |
| 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 longevity | • Ensure timely transfer to controlled conditions  
  • Ensure appropriate post-harvest handling according to propagule maturity, prevailing environmental conditions and phytosanitary conditions |

**In vitro culture and slow-growth storage**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced propagule longevity</td>
<td>• Ensure appropriate media and storage conditions, including disease management</td>
</tr>
</tbody>
</table>
| Loss of genetic integrity due to somaclonal variation             | • Avoid the use of excess growth regulators in media  
  • Limit the number of subcultures  
  • Discard any cultures exhibiting somaclonal variation |
| Mixing/mislabelling of samples                                    | • Label carefully to avoid mixing  
  • Use computer-generated barcode labels to minimize errors                          |
| Stored sample falls below viability or quantity thresholds        | • Ensure that the documentation system includes automated tools to monitor viability and inventory and flag up accessions requiring regeneration |

**Recycling and rejuvenation**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
</table>
| Loss of adaptive alleles due to selection pressures               | • Ensure appropriate media and recycling conditions  
  • Rejuvenate under controlled environmental conditions           |
| Misidentification of sample                                       | • Check container and pot labels; use bar codes                                   |
### Characterization and evaluation (in vitro)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly recorded, unreliable data</td>
<td>• Well-trained staff&lt;br&gt; • Mobile devices to record field data&lt;br&gt; • Data validation by curator and/or documentation officer</td>
</tr>
<tr>
<td>Misidentification of sample</td>
<td>• Check container labels while collecting data</td>
</tr>
</tbody>
</table>

### Characterization and evaluation (greenhouse or field)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly recorded, unreliable data</td>
<td>• Well-trained staff&lt;br&gt; • Appropriate statistical design&lt;br&gt; • Selection of appropriate locations for planting&lt;br&gt; • Appropriate cultural practices&lt;br&gt; • Mobile devices to record field data&lt;br&gt; • Data validation by curator and/or documentation officer</td>
</tr>
<tr>
<td>Misidentification of sample</td>
<td>• Use of check accessions/varieties&lt;br&gt; • Check plot labels while collecting data&lt;br&gt; • Check plot and pot labels prior to sowing and harvesting</td>
</tr>
</tbody>
</table>

### Distribution and safety duplication

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk control/mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing/mislabelling of samples</td>
<td>• Careful packaging to avoid mixing&lt;br&gt; • Labels placed inside and outside of package&lt;br&gt; • Use computer-generated barcode labels to minimize errors</td>
</tr>
<tr>
<td>Viability loss due to delayed or damaged shipments</td>
<td>• Ensure samples are dispatched promptly and use the fastest and safest way of sending.</td>
</tr>
</tbody>
</table>