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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 3.2 of the Provisional Agenda

INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Tenth Session

22–24 June 2021

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

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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 receive feedback on the utility of the Genebank Standards from a wide stakeholder base, FAO undertook a global survey of the relevant practitioners in 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 standardising genebank operations based on validated best practices.[5] However, it was indicated that the step-wise 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 *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 has prepared 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: orthodox seeds at low temperatures; vegetatively propagated plants in field genebanks; and *in vitro* cultures of meristematic tissues, respectively. The purpose of these guides is to present the information contained in the Genebank Standards in a more user-friendly format detailing the different 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 the development of an efficient and sustainable system of *ex situ* conservation. Genebanks may use the activities outlined in these guides as a basis to develop Standard Operating Procedures and Quality Management Systems for conserving germplasm collections, defining in detail how to carry out each activity.

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[1] FAO. 2014. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rev. ed. Rome. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/gbs/en/

[2] http://www.fao.org/plant-treaty/en/

[3] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/gpa/en/

[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

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

5. The Draft Practical Guides comprise systematic routine genebank operations for the conservation of orthodox seeds in seed banks, conservation in field genebanks and conservation via *in vitro* culture, respectively. These Draft Practical Guides are underpinned by the underlying principles of all genebank management,[10] as outlined in chapter 2 of the Genebank Standards.

6. The Draft Practical Guides are structured to align with Chapters 4, 5 and 6 of the Genebank Standards. Each guide has an introductory section that provides a brief overview of seed genebanks, field genebanks and *in vitro* conservation, respectively. This section includes a table summarizing the underlying principles of genebank management and their related genebank operations. Each introduction also provides a chart outlining the flow of germplasm in the respective genebanks.

7. The main sections provide general guidance for the steps and decisions required when operating the respective genebanks for each of the key activities outlined in the Genebank Standards. An additional section provides an overview of basic infrastructure and equipment required. Important sources of information and references are also provided.

8. An annex to each Draft Practical Guide reviews the risks and associated mitigation for each activity, respectively.

9. The three Draft Practical Guides are presented in Annexes 1, 2 and 3 to this document. A summary of their content and the guidance sought are presented in the document *Implementation of the Genebank Standard for Plant Genetic Resources for Food and Agriculture*.[11]

[10] 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.

[11] CGRFA/WG-PGR-10/21/2.2

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 seed storage life. Orthodox seeds can be dried and usually kept viable over longer periods of time, which distinguishes them from recalcitrant seeds, which die when they are dried.

Cereals, grain legumes, forages, most vegetables and some fruits include species that produce orthodox seed and can therefore be conserved in seed banks. The wild relatives of these crops also produce orthodox seeds, though they often require specialized treatment. Some crops that are usually propagated vegetatively, for example, potato, may produce true seeds that can be dried and stored at low temperature.

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.[12]

The conservation of orthodox seed in genebanks can be broken down into a process of interrelated operations (Figure 1). This practical guide for the conservation of orthodox seeds in genebanks suggests practices and activities 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).[13] The purpose of this guide is to present the information contained in the Genebank Standards in a more user-friendly format detailing the different actions of the genebank workflow in a sequential manner and facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis to develop Standard Operating Procedures (SOPs)[14] and Quality Management Systems[15] for conserving germplasm collections, defining in detail how to carry out each activity.

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

[12] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf (Chapter 2)
[13] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf
[14] For example, see Standard Operation Procedures (SOP) for IITA Seedbank: https://www.iita.org/wp-content/uploads/2017/SOP_for_IITA_Seedbank.pdf
[15] https://www.genebanks.org/the-platform/quality-management/

Figure 1. Major operations for the conservation of orthodox seeds in a seed genebank

Table 1: The underlying principles and related genebank operations for seed genebanks

Genebank principle	Summarized genebank operations
Identity of accessions	Passport data collected and recorded Botanical identification verified Permanent and unique accession number assigned and used in all documentation Labelling & tracking in genebank Careful processing undertaken
Maintenance of viability	Best practices followed when collecting, regenerating, processing and transporting Storage conditions optimized and monitored Regeneration undertaken when necessary
Maintenance of genetic integrity	Collecting and maintenance of samples conducted in a manner that ensures they represent original population Best practices followed during packaging, regeneration and multiplication
Maintenance of germplasm health	Quarantine procedures undertaken when/if needed Best practices followed during packaging, regeneration and multiplication Contamination monitored and managed
Physical security of collections	Risk management strategy developed and implemented Accessions safety duplicated/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, efficient and timely transfer & systems in place to support use of germplasm Relevant documentation provided to recipients of genebank material
Availability of information	Functional genebank information management system in place Passport and accession management data secured by regular data backups Passport and other relevant data available and accessible
Proactive management of genebanks	Standards of Operation developed and available to staff Data and information generated during genebank activities available to managers Well-trained staff employed and protected by Occupational Safety and Health measures Genebank staff capacities kept current and trainings provided as necessary

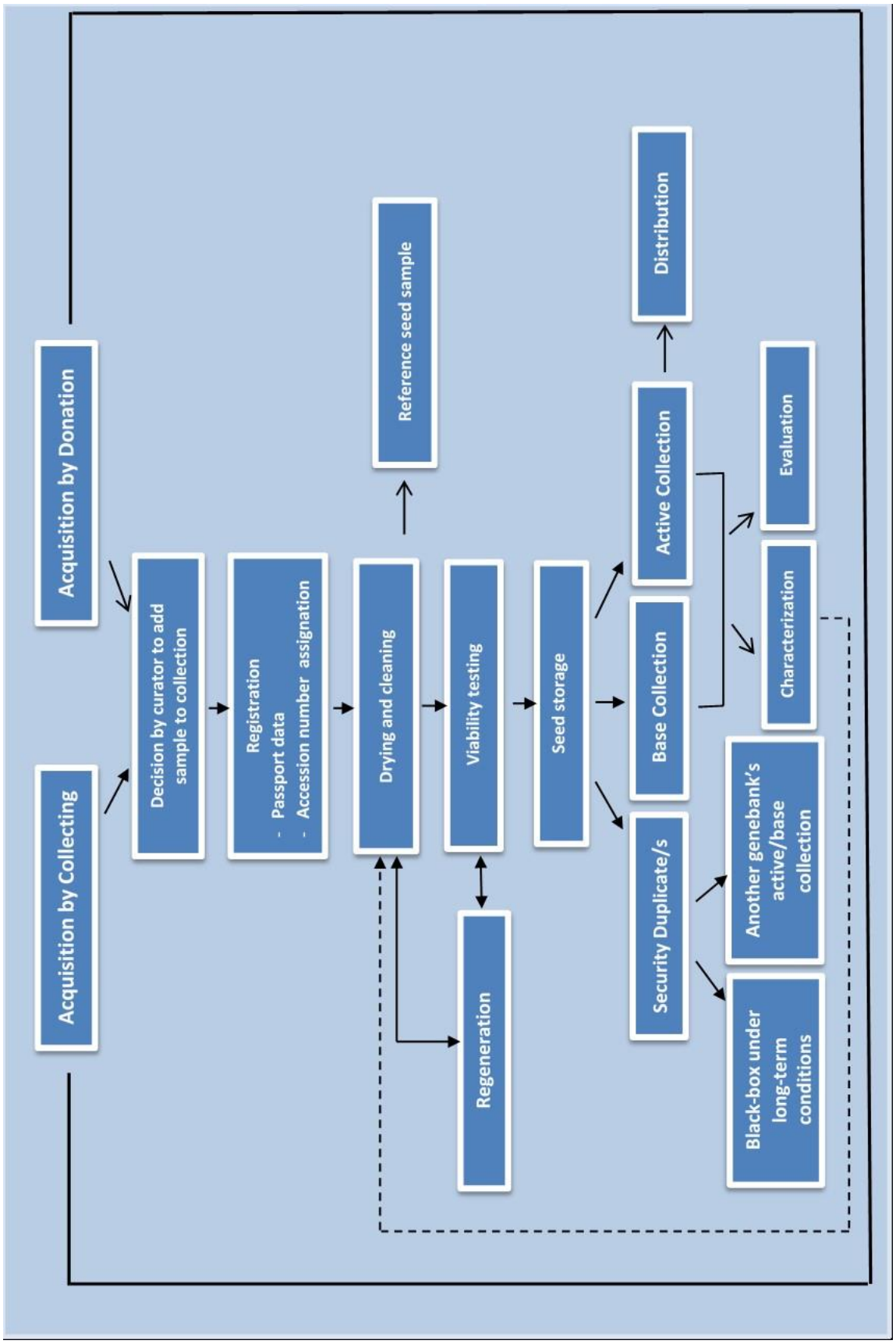

Figure 2. Flow of germplasm in a genebank for orthodox seed conservation. Each step is associated with proper documentation.

2. Acquisition of Germplasm

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

2.1 Germplasm acquired through collecting missions

✓ **A clear strategy for germplasm acquisition is developed according to your institute's mandate.**

Genebank curators may interact with breeders and other scientists before deciding on new acquisitions to ensure that collections remain manageable and meet user's needs.[16] Genebanks may also have a crop or general committee in place. It may be appropriate and useful that:

- the collecting proposal clearly states the purpose of the collecting mission, the target location and methodology;
- a collaboration with an institute or experts from the targeted area be established and guided by regulations for collecting in that area; and
- the mission is planned well in advance to ensure best practices and compliance with regulations and requirements.

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.[17]**

The process of germplasm acquisition is governed by national and international regulations. The genebank should communicate with National Focal Points for the International Treaty for Plant Genetic Resources for Food and Agriculture (Treaty) or the Convention on Biological Diversity (CBD) if other countries are involved in germplasm acquisition. The below information could assist in ensuring compliance with these regulations:

- For collecting missions in your own country, it may be necessary to contact the national competent authority to understand and be compliant 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 or community areas, prior informed consent (PIC) may be required and mutually agreed terms (MAT) [18] 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.[19]**

With the movement of germplasm, there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;

[16] Guarino, L.G., Rao, L.R. and Reid, V., 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB international: https://www.bioversityinternational.org/e-library/publications/detail/collecting-plant-genetic-diversity/

[17] See Genebank Standards (Standard 4.1.1): http://www.fao.org/3/a-i3704e.pdf

[18] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf.

[19] See Genebank Standards (Standard 4.1.1): http://www.fao.org/3/a-i3704e.pdf

- obtaining an import permit from the relevant authorities in your country;[20]
- passing samples collected through the relevant quarantine process before being transferred to the genebank; and
- regenerating 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, devoid of disease and insect pest infestations or other damage.**

Avoid collecting dispersed seeds from the ground, soiled seeds or seeds with saprophytic or pathogenic fungi/bacteria or insects, if possible, to prevent potential phytosanitary contamination. This may not be possible with crop wild relatives as they tend to shatter seeds easily at maturity.

✓ **Seeds/spikes/pods, etc. are collected from an appropriate number of individual plants, if possible, such that the germplasm is genetically representative of the population, 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 (see Box 1).[21] If the source population is of sufficient size, collecting enough seeds to avoid the need for an initial regeneration stage would be practical.[22] As a general rule, collecting more than 20 percent of the available seed of a wild population should be avoided in order to leave sufficient seeds for natural population renewal.[23]

Box 1: General guide for number of plants to sample

To attain reasonable representativeness, if possible, harvest seeds from at least 30 seed parents for cross-fertilizing species and 60 seed parents for autogamous species.

✓ **Collected samples are labelled and are not mixed during handling.**

Use indelible ink or computer generated labels (preferably with barcodes), if possible, on the seed packet to label the sample. Label placement 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.

✓ **The period between collecting, shipping and processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.[24]**

Initial viability is a major factor in seed sample longevity and it is at a maximum at the time of harvest/ collecting; viability declines as seeds begin to age. The sooner the newly harvested

[20] 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/

[21] See Genebank Standards (Standard 4.1.5): http://www.fao.org/3/a-i3704e.pdf

[22] The Crop Genebank Knowledge Base suggests storing a minimum seed quantity of 3000-4000 for a genetically homogenous sample, and 4000-12 000 for a genetically heterogeneous sample: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/conservation-mainmenu-198/seed-bank-mainmenu-199

[23] Way, M. 2003. Collecting Seed from Non-domesticated Plants for Long-Term Conservation. In: R.D. Smith, J.D. Dickie, S.H. Linington, H.W. Pritchard and R.J. Probert (eds), Seed Conservation: turning science into practice. Royal Botanic Gardens, Kew, UK. pp. 163-201.

[24] See Genebank Standards (Standard 4.1.3): http://www.fao.org/3/a-i3704e.pdf

seed samples are placed in controlled drying conditions, the more likely that a high initial viability will be achieved (see Monitoring Seed Viability).

✓ **The choice of packaging and transport allows for safe and timely delivery.**

The time needed for document processing, duration of shipment or transit time and conditions (high temperatures and/or humidity in tropical countries) is 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.
  - It may be necessary to apply pesticide or fungicide before packaging, but avoid any unnecessary chemical treatment. If applied, declare treatments on each seed package and in accompanying documentation.
- Using rigid cushioned envelopes or insulated packaging should protect samples from crushing by mechanical mail sorters and deterioration (in the case of fleshy fruits).

Transport

- For transit of long duration by road, periodic aeration of the collected material may be necessary as a precaution against viability loss.
- Sending shipments the fastest means possible, either by airfreight or courier, should avoid deterioration of seed quality and exposure to adverse environmental conditions.
- Continuous tracking of the package, if possible, will allow for expedient processing at arrival.

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[25]

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

- Associated data for each sample *obtained* as detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v. 2.1) (Box 2)[26]
- Taxonomic identification on species and intraspecifc levels if possible, plant population type, habitat and ecology, GPS coordinates, photo images and the substratum in order to provide curators and users of the germplasm with an understanding of its original context;
- Information on origin of the germplasm, traditional knowledge, cultural practices, etc., if collecting from farmers' fields; and

Box 2: Minimum passport data
As a minimum, collecting forms should contain:

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

[25] See Genebank Standards (Standard 4.1.4): http://www.fao.org/3/a-i3704e.pdf
[26] Alercia *et al*. 2015.

- If a herbarium voucher specimen is obtained as a reference from a population (for example wild species), it is important to use the same collecting number as the seed sample.

✓ **It is very important to assign a permanent and unique accession number to each seed sample added to the genebank collection.**

- Once the curator decides to accept a collected sample in the genebank, a unique accession number must be assigned. A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).
- An additional identifier, as well as another DOI, can be added to identify various seed lots of this genebank accession.

✓ **All acquisition data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

1.2 Germplasm acquired through transfer/donation

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.[27]**

- A Material Transfer Agreement (MTA)[28] or, in case of Annex 1 species under the Treaty,[29] a Standard Material Transfer Agreement (SMTA)[30] may be required and should be signed by the involved parties/proper authorities.
- For donations from institutions, plant breeders, or other germplasm providers without a 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.[31]**

With the movement of germplasm there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;
  - obtaining an import permit from the relevant authorities in your country;[32]
- passing samples through the relevant quarantine process before being transferred to the genebank;

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[27] See Genebank Standards (Standard 4.1.1): http://www.fao.org/3/a-i3704e.pdf

[28] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

[29] http://www.fao.org/3/a-bc084e.pdf

[30] https://mls.planttreaty.org/itt/

[31] See Genebank Standards (Standard 4.1.1): http://www.fao.org/3/a-i3704e.pdf

[32] 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/

- checking donated material for seed treatment that may require special handling of the seeds; and
- regenerating collected accessions with insufficient seed quantity in containment or in an isolated area according to the advice of the national phytosanitary authority.

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[33]

- It is recommended to request donors that samples be accompanied by the associated data as detailed in the FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1).[34,35]
- The associations of data with the single seed accessions must be clear, e.g. by using accession numbers and/or DOI. Data can be transferred efficiently electronically.

✓ **It is very important to assign a permanent and unique accession number to each seed sample added to the genebank collection.**

Once the curator decides to accept a donated sample in the genebank, a unique accession number must be assigned.

- A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).
- An additional identifier, as well as another DOI, can be added to identify various seed lots of this genebank accession.
- If the donated material has an accession number, a DOI or both, keep these as alternate identifiers in the passport data. This is a critical measure to ensure the tracking of material and the unambiguous association of information with the material.

✓ **All acquisition data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

[33] See Genebank Standards (Standard 4.1.4): http://www.fao.org/3/a-i3704e.pdf

[34] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

[35] See Box 2

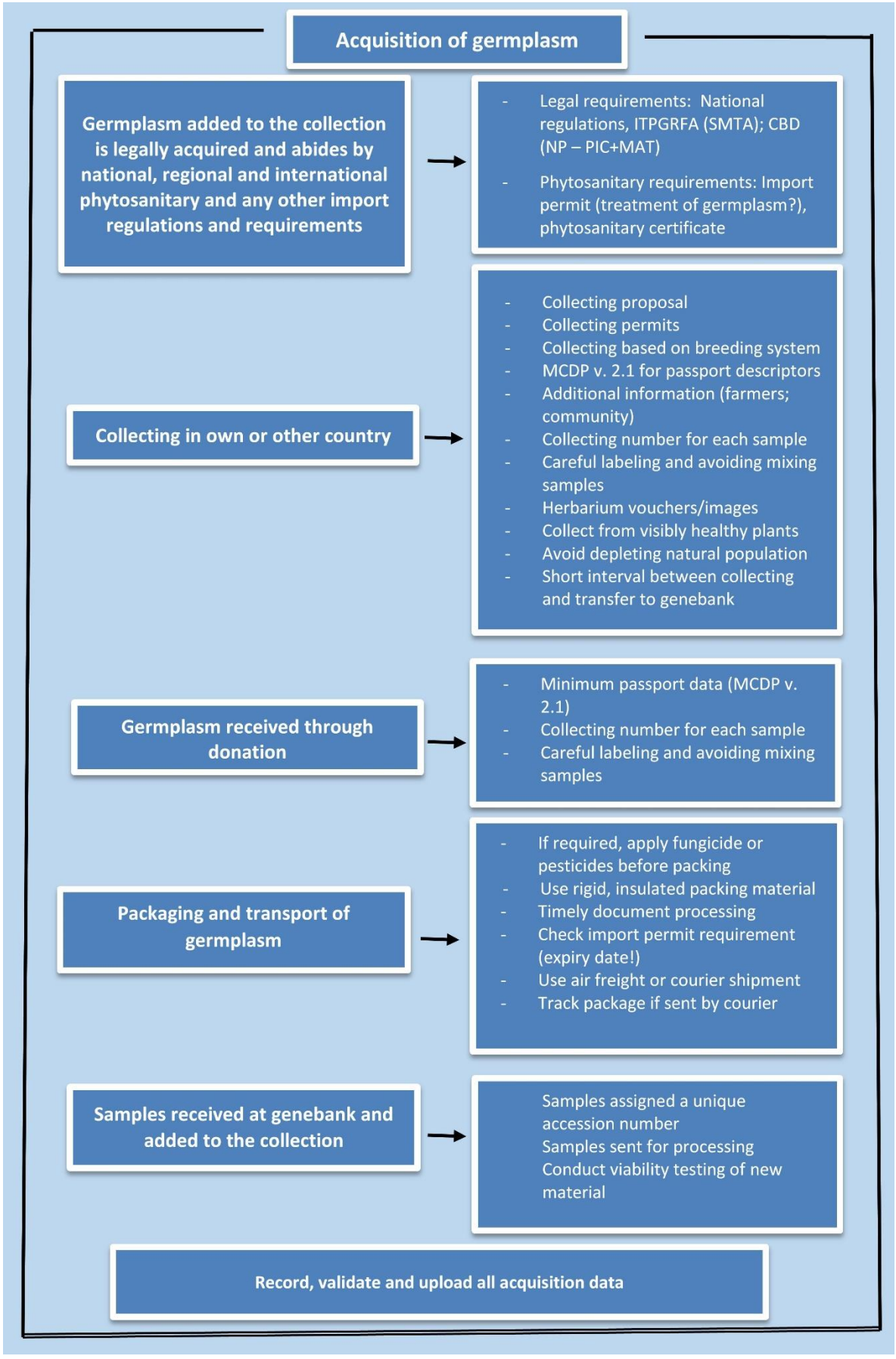

Figure 3. Summary diagram for acquisition of germplasm

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.

✓ **Collected samples are threshed and cleaned.**

Cleaning samples in the initial processing into genebanks is an essential component of sample management.

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

The optimal moisture content for storage varies among species and sometimes even among genotypes within a species. Available online tools can be used to check the equilibrium moisture content achieved under different drying conditions.[36] For hermetic storage under long-term conditions, optimal moisture content is typically around 3 percent for oily seeds, and around 7 percent for starchy cereals. These can generally be achieved by drying seeds to equilibrium in a controlled environment of 5-20°C and 10-25 percent relative humidity.[37] It is helpful to:

- determine the appropriate method to dry seeds, depending on type of sample (fleshy fruit, dry fruits or seeds) the number and size of samples to be dried at any one time, local climatic conditions and the financial resources available;[38] and
- monitor drying using a digital moisture sensor, indicator silica gel or low-cost dial hygrometers, if available.

✓ **Samples meant for long-term storage are packaged under controlled conditions, in clearly labelled airtight containers after drying.[39]**

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

- filling the container to minimize the air gap above the seeds (ideally keep a range of container sizes to suit the volume of seeds in different accessions) helps to avoid seeds re-absorbing moisture;
- placing both an outer and inner label (preferably barcoded) for each sample to ensure that the material is properly identified; and
- ideally, storing enough seeds for three regenerations;[40]

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.

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[36] Royal Botanic Gardens, Kew. 2018. *Seed Information Database (SID). Version 7.1* [online]. [Cited 3 March 2018]. http://data.kew.org/sid/

[37] See Genebank Standards (Standard 4.2.1): http://www.fao.org/3/a-i3704e.pdf

[38] See Rao, N. K., J. Hanson, M. E. Dulloo, K. Ghosh, D. Nowell, and M. Larinde. 2006. Handooks for Genebanks No. 8: Manual of Seed Handling in Genebanks. Rome: Biodiversity International. Available at: https://www.bioversityinternational.org/e-library/publications/detail/seed-handling-in-genebanks/.

[39] See Genebank Standards (Standard 4.2.2): http://www.fao.org/3/a-i3704e.pdf

[40] The Crop Genebank Knowledge Base suggests storing a minimum seed quantity of 3,000-4,000 for a genetically homogenous sample, and 4000-12 000 for a genetically heterogeneous sample: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/conservation-mainmenu-198/seed-bank-mainmenu-199

✓ **Samples of long-term base collections are stored at the lowest temperature possible.**

A suitable temperature for long-term storage is –18 °C.[41] 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 back up 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 spent 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 on the cold seeds.

✓ **Samples that will be accessed often (and are likely to be depleted before viability falls to the regeneration level) are packaged in clearly labelled, leak-proof and easily-opened containers after drying.**

Active collections consist of germplasm that may be used for distribution, regeneration/ multiplication, characterization and evaluation. Best practices include:

- placing both an outer and inner label (preferably barcoded) for each sample to ensure that the material is properly identified;
- using indicator silica gel sachets in the container to monitor ingress of moisture, if available; and
- ideally, storing enough seeds for distribution and regeneration.[42]

✓ **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.[43] It is very important to have back up power supply 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 the container to avoid condensation on the cold seeds.

✓ **A small reference sample of seeds is kept separately for each accession.**

It is helpful to have a reference seed sample for each accession, ideally of the most original sample available. If possible, approximately 50 seeds are kept in a small plastic or glass vial or sealed plastic bag with both an outer and inner label (preferably barcoded) to ensure that the material is properly identified.[44] 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, date of inclusion into collection, etc. The

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

[42] Optimal seed numbers can range from 4000 (self-pollinated) to 12 000 (cross-pollinated): Upadhyaya, H.D. & Gowda, C.L. 2009. Managing and Enhancing the Use of Germplasm – Strategies and Methodologies: http://genebank.icrisat.org/PDF/Section/Section4,5.pdf

[43] See Genebank Standards (Standard 4.2.4): http://www.fao.org/3/a-i3704e.pdf

[44] See Genebank Standards (Standard 4.4.3): http://www.fao.org/3/a-i3704e.pdf

use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

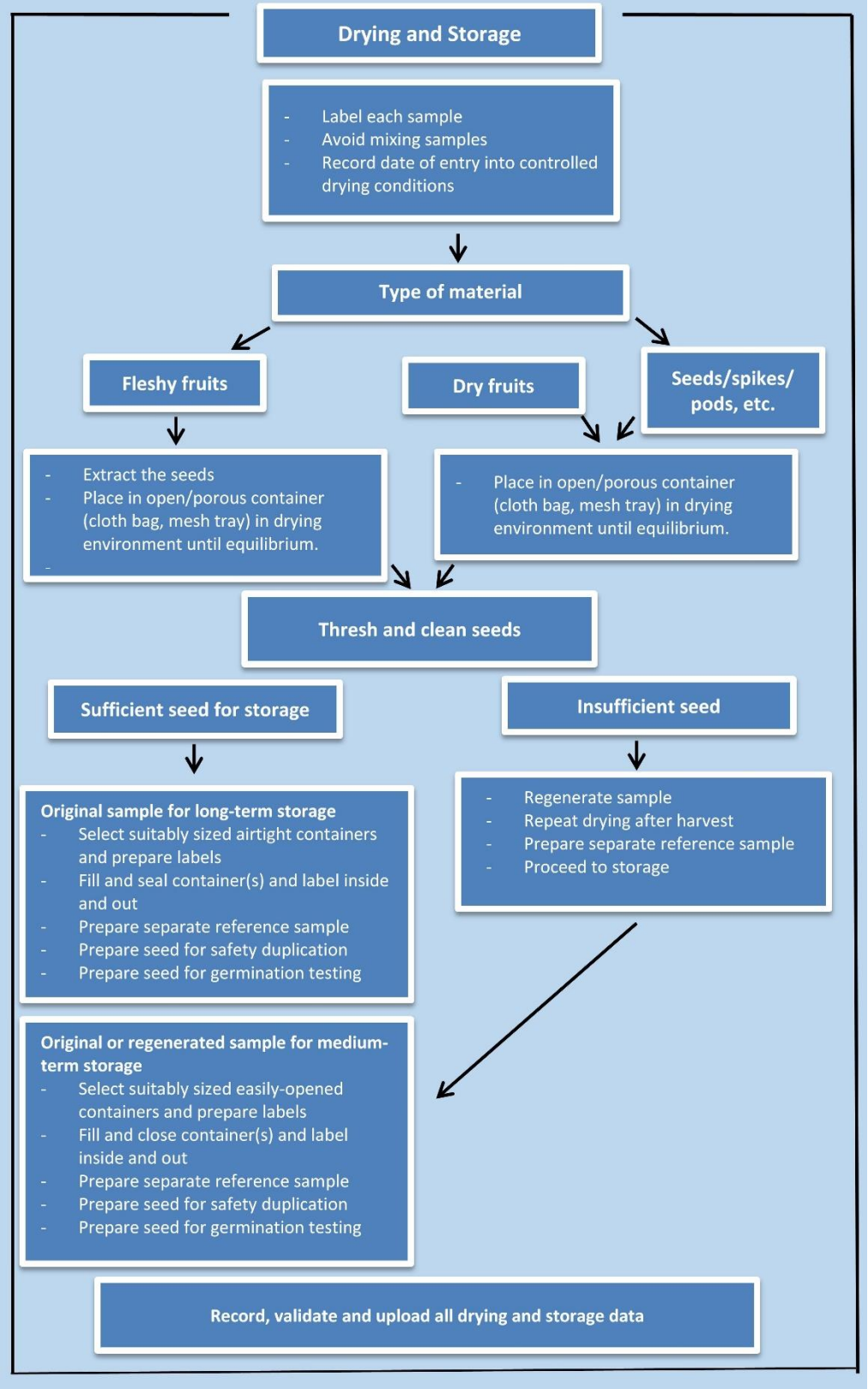

Figure 4. Summary diagram for drying and storage of germplasm

4. Seed Viability Monitoring

The genebank is recommended to have a documented policy and/or procedure, as applicable, describing the viability[45] monitoring system used to detect falls in viability.

✓ **Seed germination testing follows optimized and well-documented procedures.**

It is important to use standard protocols so that viability monitoring tests are comparable, also over time, ideally using randomized and replicated testing procedures.[46] Many genebanks have developed in-house protocols. A number of resources can be found on-line:

- The International Seed Testing Association (ISTA)[47] and the Association of Official Seed Analysts (AOSA)[48] publish germination testing guidelines, 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.[49]
- Kew's Seed Information Database includes details of successful germination protocols for more than 12 424 wild species, including crop wild relatives.[50]

✓ **Initial seed germination testing is conducted as soon as possible after obtaining the accession.**[51]

Ideally, all newly acquired seed germplasm 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 minimises the rate of viability decline between seed collecting and storage. Planning the workflow of your genebank will increase efficiency and save resources.

A viability test should ideally also be conducted after regeneration. Some species have a period of primary dormancy and they should not be tested directly after collecting or harvest. Older seeds may have secondary dormancy. Literature about specific methods to break seed dormancy must be consulted.

✓ **Sometimes seeds that germinated in viability tests need to be planted directly for subsequent regeneration**

If the viability is very low it may be that the only way to rescue the accession is to grow those seedlings that germinated. In this case, transplant germinated seeds directly into pots for growing in the greenhouse. This situation should be prevented if possible to avoid compromising the genetic integrity of the original sample.

✓ **The minimum viability for most accessions 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.[52] A

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[45] Viability is usually assessed by testing germinability, taking into account dormant seeds that are viable but do not germinate.

[46] See Genebank Standards (Section 4.3): http://www.fao.org/3/a-i3704e.pdf

[47] https://www.seedtest.org/en/home.html

[48] https://www.analyzeseeds.com/

[49] https://cropgenebank.sgrp.cgiar.org/images/file/procedures/guidelines%20for%20testing%20germination%20of%20the%20most%20common%20crop%20species.pdf

[50] http://data.kew.org/sid/

[51] See Genebank Standards (Standard 4.3.1): http://www.fao.org/3/a-i3704e.pdf

[52] See Genebank Standards (Standard 4.3.2): http://www.fao.org/3/a-i3704e.pdf

lower threshold may be acceptable for certain accessions that do not normally reach 85 percent (for example, some forest and wild species).[53] 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, including wild and forest species that do not normally reach high levels of 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.

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

Results from the first viability test provide the benchmark against which future monitoring tests are compared. Viability monitoring aims to detect significant falls in viability and 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 suggested practices could be considered:

- determining, as far as possible, optimal testing intervals to maintain samples above viability thresholds for each species, noting species differences in seed longevity;[54]
- 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;[55]
- in the absence of data, setting monitoring intervals for medium-term collections depending on the expected longevity of species, for example 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.[56]

✓ **The genebank information management system ideally includes tools to report when the next viability monitoring test is due.**

✓ **All seed viability monitoring data, including associated metadata, is 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 seed, germination percentage, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

[53] See Genebank Standards (Standard 4.3.4): http://www.fao.org/3/a-i3704e.pdf

[54] Nagel, M. & Börner, A. 2010. The longevity of crop seeds stored under ambient conditions. Seed Science Research, 20(1): 1–12. https://doi.org/10.1017/S0960258509990213

[55] See Genebank Standards (Standard 4.3.3): http://www.fao.org/3/a-i3704e.pdf

[56] Hay, F.R. & Whitehouse, K.J. 2017. Rethinking the approach to viability monitoring in seed genebanks. Conservation Physiology, 5(1). https://doi.org/10.1093/conphys/cox009

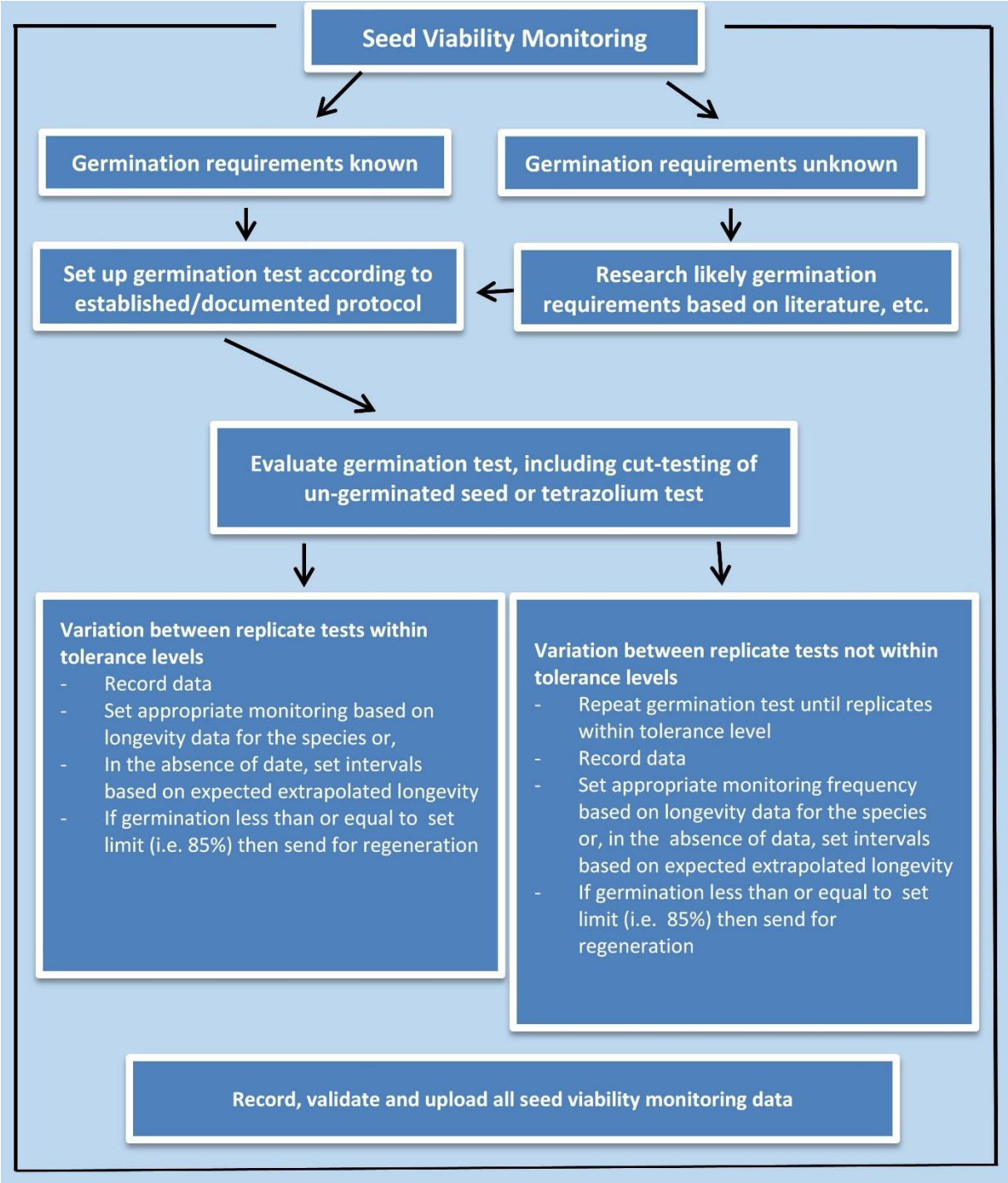

Figure 5. Summary diagram for viability monitoring of germplasm

5. Regeneration

The genebank is recommended to have a documented policy and/or procedure, as applicable, for regeneration[57] of germplasm, including step-by-step instructions to monitor 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 tools to check seed inventory and seed viability and report when regeneration is required.**

Practical considerations are also important to avoid planting an overwhelming number of accessions. Consider regularly monitoring when regeneration is due and plan accordingly.

✓ **Accessions are regenerated when seed viability or seed quantity fall below the respective regeneration thresholds**.

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 the viability drops below 85 of the determined threshold;[58]
- regenerating when the remaining seed quantity is less than what is required for three sowings of a representative population of the accession; and
- regenerating when there is an insufficient number of seeds for long-term storage.

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

Understanding the genetics and structure of the genebank collection as a whole facilitates making informed decisions about regeneration procedures, including species-specific requirements. Best practices to consider include:

- selecting a regeneration environment that is ecologically similar to the original collecting site to the best possible extent to reduce possible selection pressures;
- using the most-original-sample stored to regenerate accessions for long-term storage and seeds from the active collection to regenerate accessions for medium term storage;
- creating both hard and soft copies of field maps developed before planting;
- clearly labelling regeneration plots (preferably with bar-codes);
- establishing an effective population that represents the genetic composition of the accession;[59]
- 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, such as taking the crop breeding system into account, which may require physical isolation and provision of pollinating services;
- removing plants that are growing outside the planted rows;
- utilizing herbarium specimens and images and reference seed samples, if available, to verify accession identity including taxonomic identification and verification;
- removing phenotypically different plants when there is absolute certainty that they are rogue plants derived from contamination of the original accession;

[57] Note that we are using the term regeneration to depict both regeneration and multiplication.
[58] See Genebank Standards (Standard 4.4.1): http://www.fao.org/3/a-i3704e.pdf
[59] 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.

- paying special attention to the regeneration need of wild species to avoid the entire or partial loss of poorly adapted accessions, such as growing at alternative sites or in greenhouses, growing under shaded conditions, etc.;
- observe for occurrence of diseases and pests during regeneration; as measures to combat them and avoid chemical interventions if possible;
- conduct a basic characterization and compare results with previous records on the accession, herbarium specimens, documented images, and reference seed sample taken when accession entered the genebank to ensure true to type performance;
- if feasible, consider taking and storing images from plants during each regeneration and of seeds for future reference;
- observe phenotypic heterogeneity that may be based on genotypic heterogeneity and record this; consider separating an accession into distinct populations to ensure diversity is preserved and can be characterized and utilized more efficiently;[60]
- add a specific identifier to the seed lot after harvest that allows tracing all generations of harvested seed lots? 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 identify; and
- avoiding mixing and mislabeling 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, number of plants harvested, yield, etc. The use of indelible ink and writing clearly and legibly when recording data is recommended. Mobile devices such as smartphones or tablets save time, avoid transcription errors and ease transfer into the genebank information management system. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error.

[60] See: Lehmann C. and Mansfeld R. 1957 Zur Technik der Sortimentserhaltung. Die Kulturpflanze 5, 108–138.

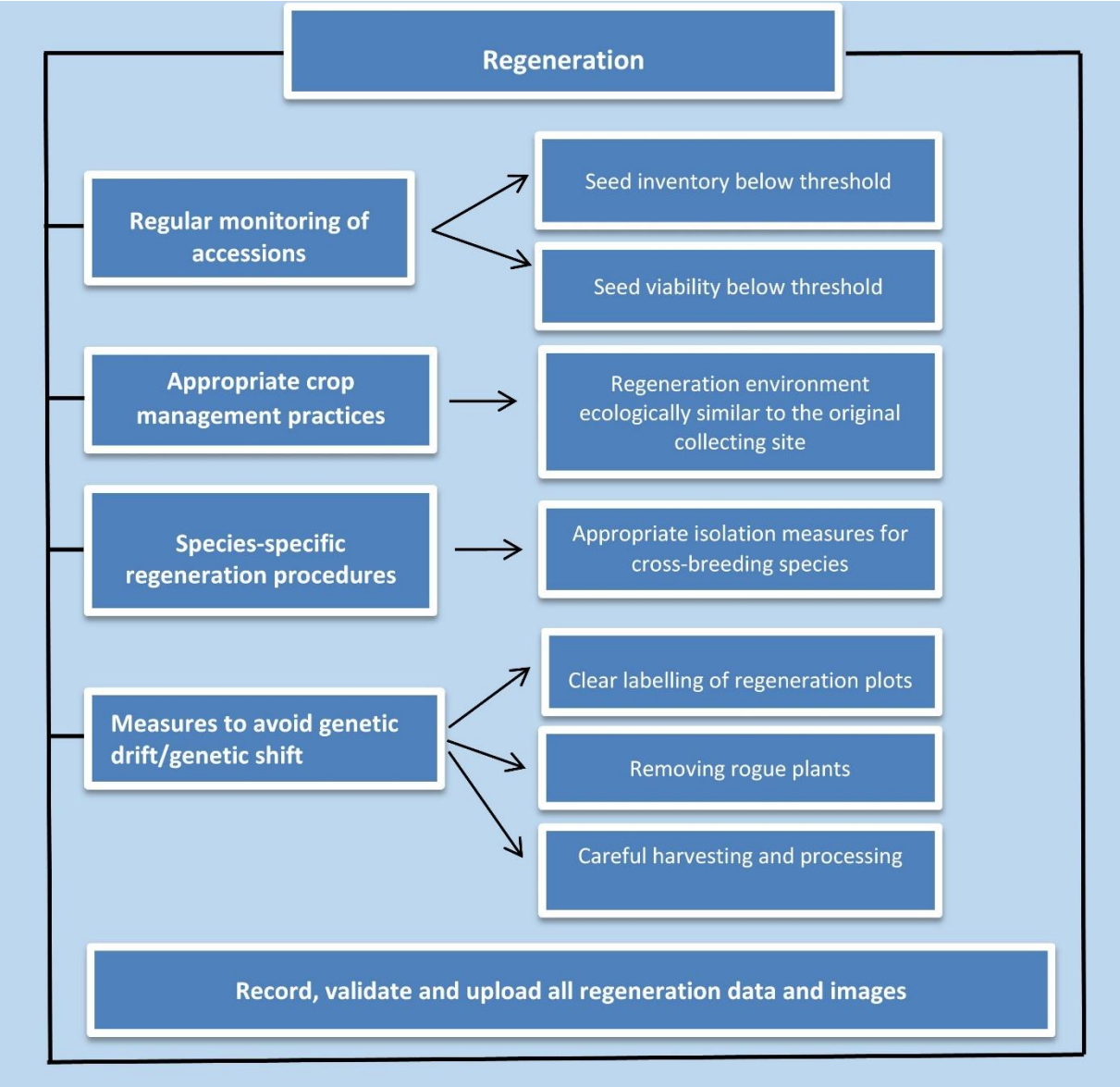

Figure 6. Summary diagram for regeneration of germplasm

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 is obtained, descriptors used (taxonomic, morphological, phenotypic, biochemical, nutritional, physiological and molecular), and the manner in which the data is collected and validated.

✓ **Characterization data is obtained for as many accessions as possible and as soon as possible.**
Ideally, all accessions should be characterized soon after acquisition.[61] Characterization can be combined with regeneration, particularly for self-pollinating species whose accessions can be planted in proximity of each other. In outcrossing species, it is preferable to plant special characterization nurseries with accessions planted side by side for collecting reliable data. The sooner the information is available, the more likely the accession will be used. Best practices to consider include:

- using an augmented design, possibly replicated, with carefully chosen check accessions or varieties (controls), as they facilitate the generation of reliable characterization data;[62]
- it is advisable to characterize larger number of accessions at the same time to be efficient;
- creating both hard and soft copies of field maps developed before planting; and
- clearly labelling plots (preferably with bar-codes).

✓ **Germplasm is characterized for a set of highly heritable morphological traits to describe the phenotype of plants, and species-specific characterization procedures are based upon standardized and calibrated measuring formats and categories, following internationally agreed descriptor lists as far as possible.[63]**
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,[64] The International Union for the Protection of New Varieties of Plants(UPOV),[65] and the National Plant Germplasm System (NPGS) of the United States).[66] If there are no existing descriptor lists for a species, it is recommended to use Bioversity International's Guidelines for Developing Crop Descriptor Lists.[67] It may be helpful to consider:

- utilizing 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 an accession is important;

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[61] See Genebank Standards (Standard 4.5.1): http://www.fao.org/3/a-i3704e.pdf
[62] See section 6.4: https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Design_and_analysis_of_evaluation_trials_of_genetic_resources_collections_731.pdf
[63] See Genebank Standards (Standard 4.5.2): http://www.fao.org/3/a-i3704e.pdf
[64] https://www.bioversityinternational.org/e-library/publications/descriptors/
[65] https://www.upov.int/test_guidelines/en/
[66] https://www.ars-grin.gov/npgs/cgclist.html
[67] Bioversity International. 2007. Guidelines for the development of crop descriptor lists. Bioversity Technical Bulletin Series, 13. Available at: https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=1053&cHash=39138c10e405dcf0f918c6670c877b4f

- taking measurements at the plant level rather than at the plot level for crops with high levels of variability, to capture the 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;[68] and
- for some purposes it may be required to create pure lines based on single plant off-springs in self-pollinating plants.[69]

✓ **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 as well as help identify mislabeled 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 biochemical markers, DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.[70] 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, check accessions or varieties used, descriptor measured and results, date recorded, staff responsible, laboratory techniques (molecular, etc.), and dates carried out. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

✓ **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.

[68] See: Lehmann C. and Mansfeld R. 1957 Zur Technik der Sortimentserhaltung. Die Kulturpflanze 5, 108–138.
[69] Diederichsen A. and Raney J.P. 2008. Pure lining of flax (*Linum usitatissimum* L.) genebank accessions for efficiently exploiting and assessing seed character diversity. Euphytica 164, 255-273.
[70] A number of resources on the various molecular marker technologies available are available online and in print. Please see Further Information/Reading.

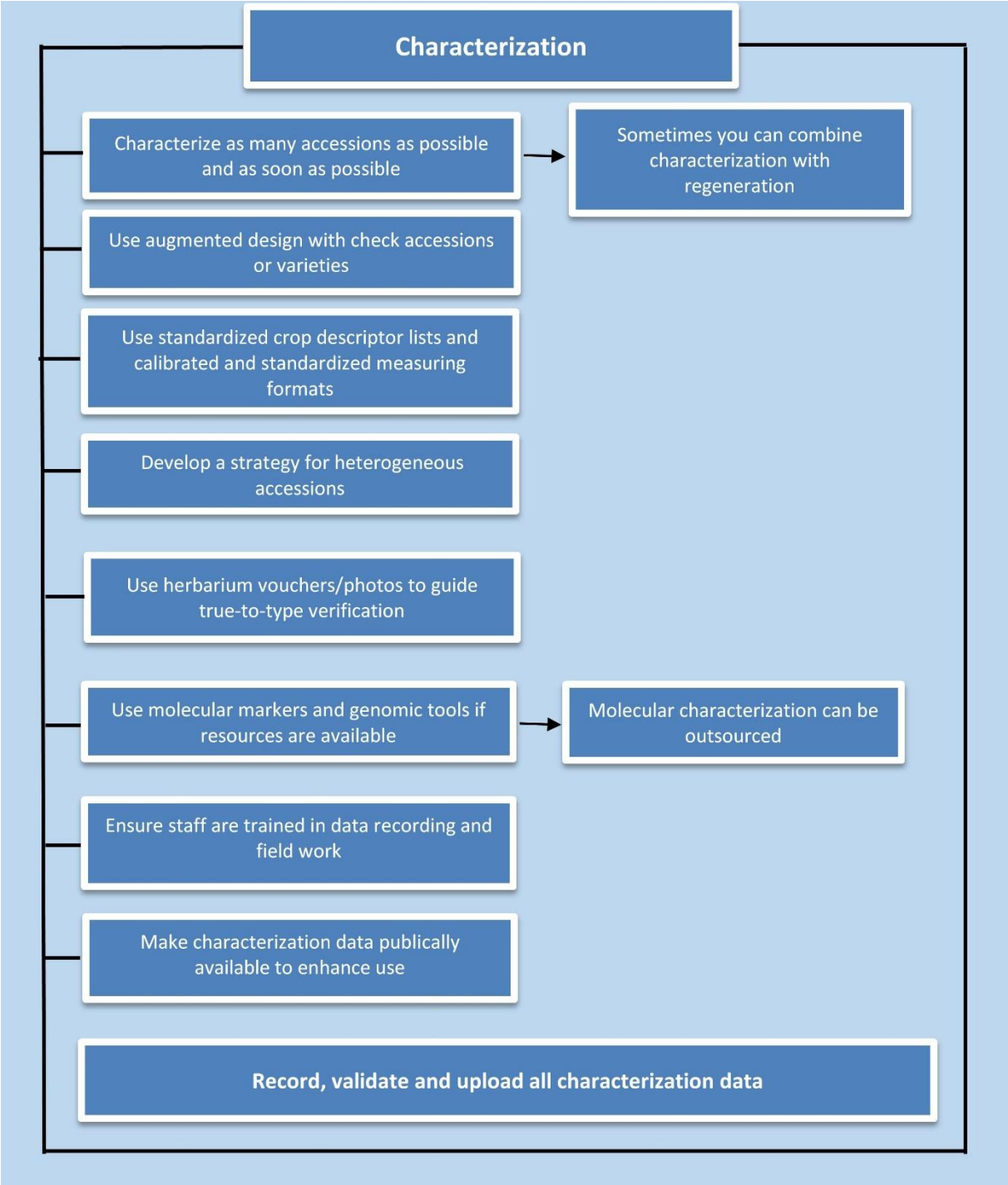

Figure 7. Summary diagram for characterization of germplasm

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 multi-location, 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 is analyzed and validated. The methods/protocols, formats and measurements for evaluation should be properly documented with citations.

✓ **Evaluation data is obtained for as many accessions as practically possible, through laboratory, greenhouse and/or field trials, as may be applicable.**[71]

Ideally, all accessions should be evaluated to maximize their utility. In reality, genebanks usually are 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 to request that data be sent back for inclusion in the genebank information management system.

✓ **Experimental designs with replicates are utilized and evaluations conducted in different environments and/or over multiple years.**[72]

Traits measured during evaluation, such as yield and plant height, etc., are mostly quantitative, subject to environmental interaction, and often multigenetically inherited and more difficult to measure. This also applies to agronomic data such as yield or yield components that show strong genotype by environment (G x E) interactions, hence 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, 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 soft 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 enable the comparison of data across institutions and countries (see Characterization section).[73]

✓ **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, number of replications, check accessions or varieties used, descriptor measured and results, date recorded, staff responsible, laboratory techniques (molecular, etc.) and dates carried out. The use of indelible ink (or pencil)

[71] See Genebank Standards (Standard 4.6.2): http://www.fao.org/3/a-i3704e.pdf
[72] See Genebank Standards (Standard 4.6.3): http://www.fao.org/3/a-i3704e.pdf
[73] See Genebank Standards (Standard 4.6.1): http://www.fao.org/3/a-i3704e.pdf

and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

✓ **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 its use (see Documentation). The publishing of evaluation data will also promote the use of the germplasm collection, especially by plant breeders.

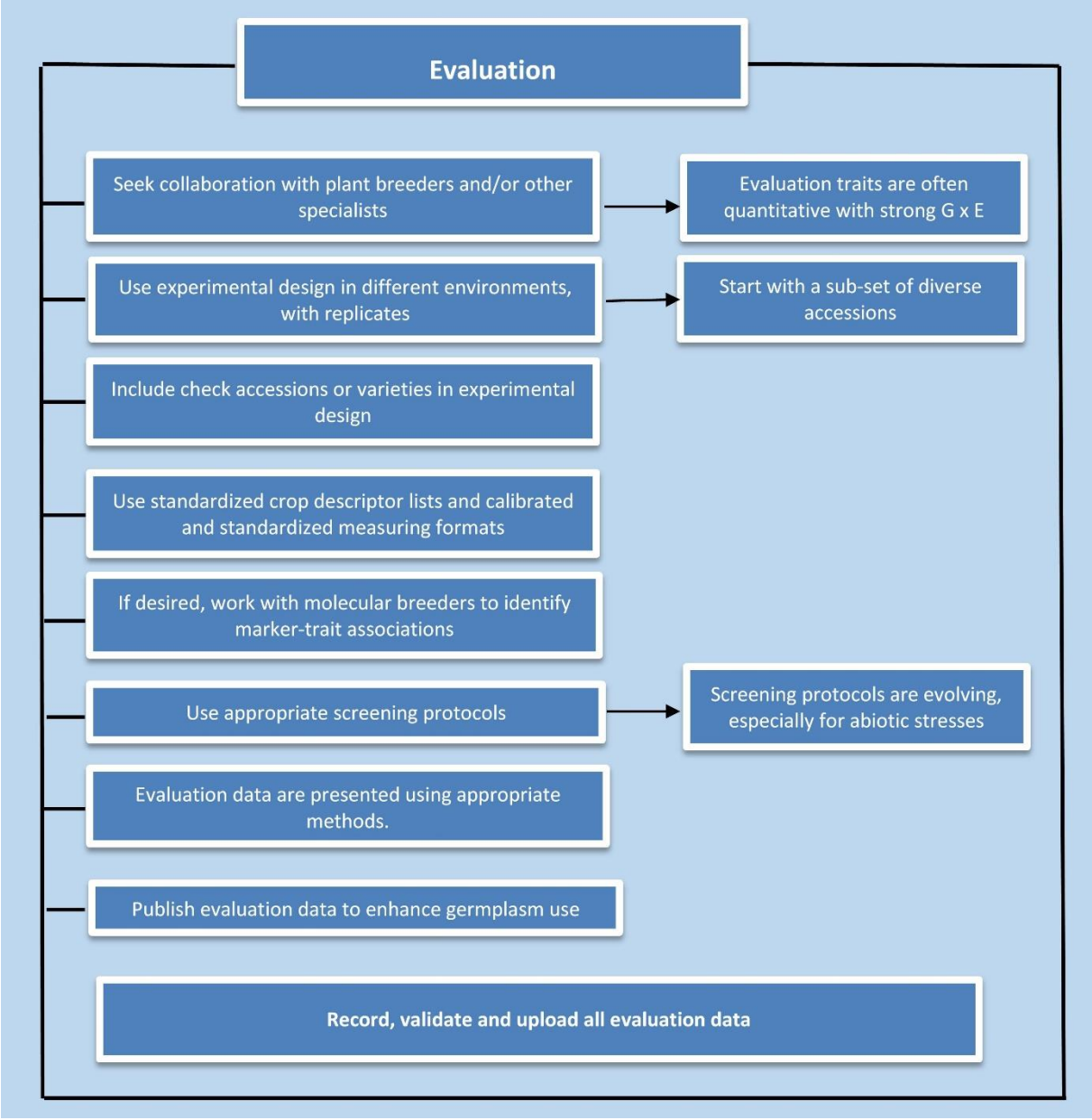

Figure 8. Summary diagram for evaluation of germplasm

8. 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 programs.**

Documentation of passport data of accessions using FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1)[74] and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation[75] facilitates data exchange and comparison across different countries and institutions. Passport data is ideally available for all accessions in the genebank collection.[76] A unique and permanent accession number is a key element of proper documentation and identification and must be assigned to each accession upon accepting it into the genebank collection. In addition, different seed lots or generations of a seed accessions should be identified uniquely. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)[77] is an additional option for information sharing across different information systems and different communities but cannot replace the genebank's accession number.

✓ **A genebank information management system is developed specifically for your genebank or one of the several systems available is used/adapted.**

The genebank information system ideally is designed to manage all data and information generated relating to all aspects of *ex situ* conservation and use of germplasm, including passport, characterization, evaluation and seed storage and management data and metadata. Built-in routines to continuously check seed inventory and seed viability and report when regeneration is required should not be missing.

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.[78] Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),[79] the German Genebank Information System (GBIS),[80] Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa)[81] and the SESTO Gene Bank Documentation System of the Nordic Genetic Resource Centre.[82]

✓ **Data are publically available in a search-query database, if possible.**

Publishing data of the genebank holdings increases the opportunities for use of the germplasm conserved 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

[74] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
[75] See Characterization and Evaluation sections.
[76] See Genebank Standards (Standard 4.7.1): http://www.fao.org/3/a-i3704e.pdf
[77] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
[78] https://www.grin-global.org/
[79] http://seed.worldveg.org
[80] http://www.ipk-gatersleben.de/en/genebank/genebank-documentation/genebank-information-system
[81] http://alelo.cenargen.embrapa.br/alelo_en.html
[82] https://sesto.nordgen.org/sesto/index.php?thm=sesto

Crop Diversity Trust.[83] It allows sharing accession data from genebanks around the world, and facilitates the ordering of material. Genesys includes accession-level passport, characterization and evaluation data as well as environmental information associated with accession collecting sites. Another option for making publically accessible passport data of genebank accessions is provided by the FAO World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS).[84] By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals,[85] WIEWS stores and publishes accession-level passport data of the largest global inventory of *ex situ* collections.[86]

✓ **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[87].**

Trained staff responsible for data recording and data entry supports quality control 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. Validation of data by genebank curators and documentation officers before being uploaded into the genebank information management system is recommended.

✓ **Paper data are digitalized and measures in place to monitor hand written and electronic data entries checked for transcription errors.**

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

[83] https://www.genesys-pgr.org/welcome
[84] http://www.fao.org/wiews/en/
[85] https://unstats.un.org/sdgs/metadata?Text=&Goal=2&Target=2.5;
[86] http://www.fao.org/wiews/data/ex-situ-sdg-251/overview/en/
[87] See Genebank Standards (Standard 4.7.2): http://www.fao.org/3/a-i3704e.pdf

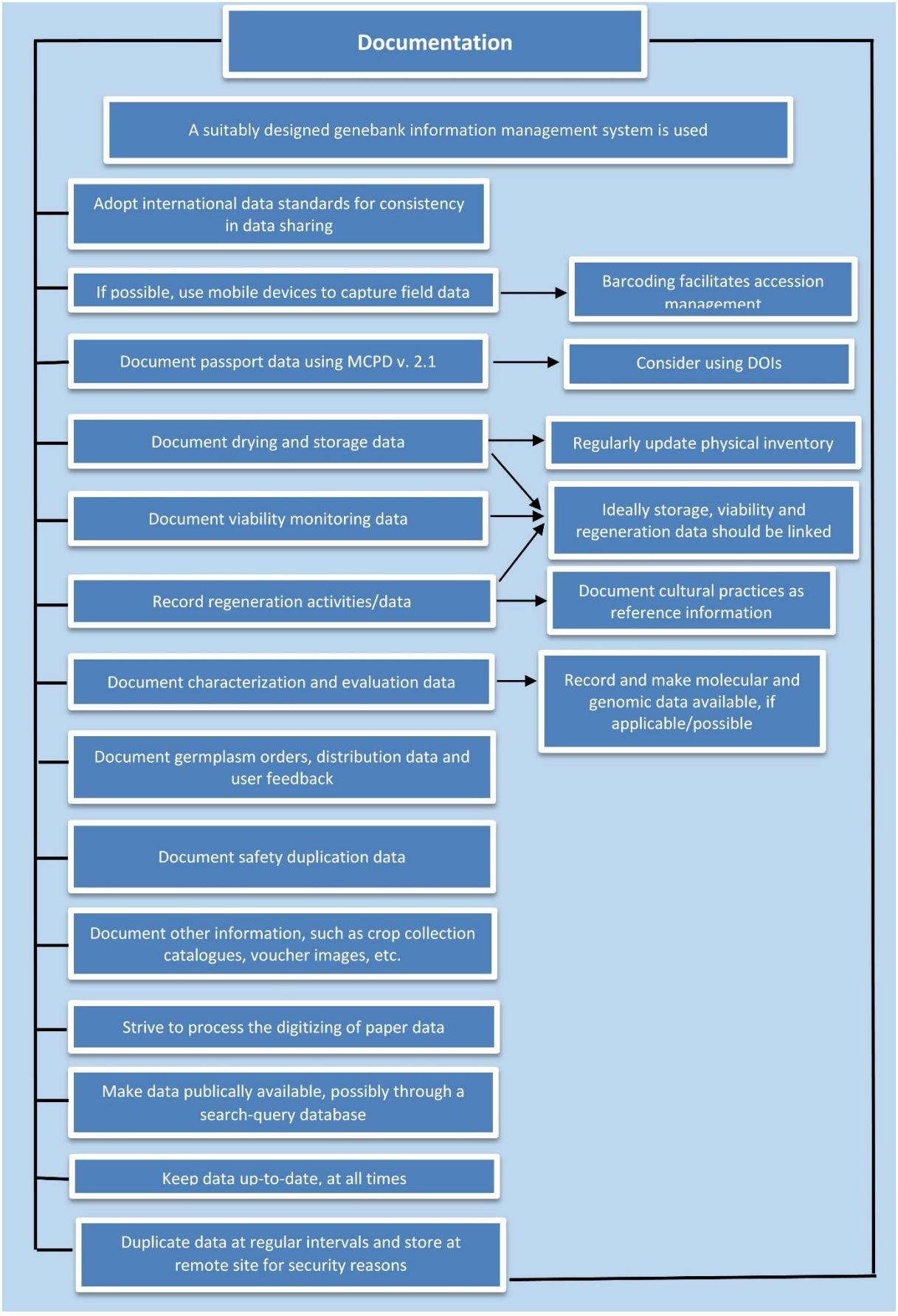

Figure 9. Summary diagram for documentation

9. Distribution and Exchange

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

✓ **The genebank complies with national, regional and international regulations and agreements.[88]**

The process of germplasm distribution is governed by national and international regulations. The below information should assist in ensuring compliance:

- The genebank should communicate with National Focal Points for the Treaty or the CBD if other countries are involved in germplasm distribution.
- If your country is a signatory to the Treaty and you are distributing germplasm of crops or species listed under Annex 1 of the Treaty[89] 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).[90]
- If your 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).[91, 92]

✓ **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.[93] For accessions with too little seed at the time of request and in the absence of a suitable alternative accession, samples are supplied after regeneration/ multiplication, based on a renewed request. For some species and for some uses, a smaller number of seeds is sufficient.

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

✓ **The time span between receipt of a request for seeds and the dispatch of the seeds is kept to a minimum.[94]**

✓ **Samples are labelled carefully and are not mixed during handling.**

Correctly labelled samples, preferably with computer-produced labels to reduce transcription errors in names and numbers, and placement of an outer and inner label for each package ensures that the material is properly identified.

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[88] See Genebank Standards (Standard 4.8.1): http://www.fao.org/3/a-i3704e.pdf
[89] http://www.fao.org/3/a-bc084e.pdf
[90] https://mls.planttreaty.org/itt/
[91] An example of a MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively a SMTA can be used or adapted.
[92] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf
[93] See Genebank Standards (Standard 4.8.4): http://www.fao.org/3/a-i3704e.pdf
[94] See Genebank Standards (Standard 4.8.3): http://www.fao.org/3/a-i3704e.pdf

- ✓ **All required documentation is included inside the shipment (for the recipient) and attached to the outside of the container for the customs officials to guarantee smooth processing during transit and at the border of the destination country.**[95]

  It is recommended to include all required documentation inside the shipment (for the recipient) and attach to the outside of the container the necessary documentation for the customs officials to guarantee smooth processing during transit and at the border of the destination country. Documentation to consider include:

  - a simple packing list with the accession numbers of the seed lots if the genebank information management system allows for on-line access to accession information;
  - data on accessions (including an itemized list with accession identification, seed lot/generation identification, number and/or weights of samples, and key passport data);
  - import permit, phytosanitary certificate, or customs declaration, if appropriate; and
  - characterization and evaluation data of the accessions, if possible (in the ideal case the accessions number allows retrieving this data from the genebank information management system);

- ✓ **The choice of packaging and transport allows for safe and timely delivery.**

  Ensure that the material reaches the destination genebank in good condition considering 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.

- ✓ **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, request date, samples requested, samples sent, number of seeds per sample, weight, reference to phytosanitary certificate and SMTA[96] or MTA;[97] shipping log, feedback from user, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

- ✓ **The delivery and condition of the germplasm on arrival at its destination is followed up to confirm that germplasm has reached the recipient in a minimum time.**

  The supplying genebank is recommended to follow up the delivery and condition of the germplasm on arrival at its destination to confirm that germplasm has reached the recipient in a minimum time. It is suggested to track shipment and follow up with the recipient as to the status and performance of the distributed germplasm.

[95] See Genebank Standards (Standard 4.8.2): http://www.fao.org/3/a-i3704e.pdf
[96] https://mls.planttreaty.org/itt/
[97] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

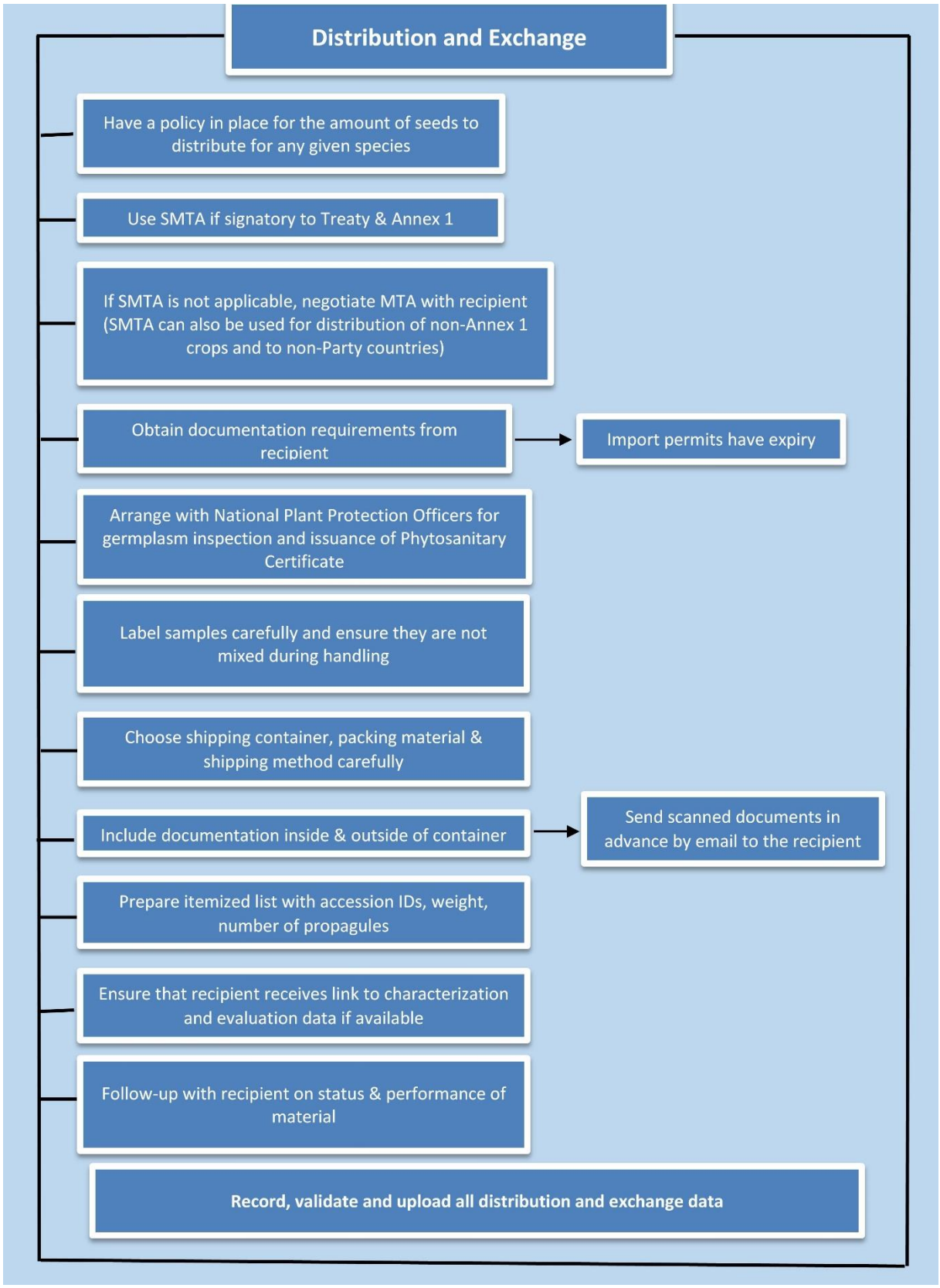

Figure 10. Summary diagram for distribution and exchange of germplasm

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 to check for fulfilment of legal, phytosanitary and other regulations and requirements and step-by step-instructions of consignment preparation, post-consignment follow-up, shipment schedules and monitoring of the viability of safety-duplicated material.

- ✓ **A safety duplicate sample for every original accession is stored in a distant area, under the same or better conditions than those in the original genebank.**[98]

  Safety duplicates are generally deposited in a base collection at a different location, usually in another country. Safety duplication can also be the inclusion of accessions into a genebank where they are actively managed. The location is chosen to minimize possible risks and provides the best possible management and/or storage facilities. Safety duplicates require a location with adequate facilities and staff. In addition, many genebanks send 'black box' samples to the Svalbard Global Seed Vault, as a safety backup. The selection of and clear agreement with the chosen holder of the safety duplicate are critical:

  - in a socio-politically and geophysical stable location; and
  - that has good management capabilities to provide appropriate conditions to the duplicated accessions and is not constrained by financial and human resources.

- ✓ **A legal agreement setting out the responsibilities of the depositing and the recipient genebank with the terms and conditions under which material is maintained and managed is in place.**

  If the holding genebank does not already have an agreement with another genebank to duplicate the original accessions, it is recommended to consider where best they could be duplicated.

- ✓ **The genebank complies with legal, phytosanitary and other regulations and requirements and each safety duplicate sample is accompanied by relevant associated information.**

  Discussions with the host genebank early in the planning process on the documentation (genebank and host country) required and an assessment of the customs and quarantine procedures, will be beneficial in ensuring timely dispatch of materials.

- ✓ **The safety duplicate is of high quality and of sufficient quantity.**

  It is the depositor's responsibility to ensure that the deposited material is of high quality, and in the case of a black box to monitor viability over time and to use their own base collection to regenerate the accessions. Best practices to consider include:

  - duplicating clean and healthy material;
  - ensuring that the size of safety-duplicated samples is sufficient to conduct at least three regenerations; and
  - preparing and identifying a subset of materials to use for viability testing in the future.

- ✓ **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 germination levels for at least 10 years and that samples are correctly labelled, preferably with computer-produced labels to reduce transcription errors in names and numbers. Best practices include:
  - packaging all seed samples for safety duplication in well labelled, vacuum-sealed trilaminate aluminum foil packet seamed on all four sides with no gusset; and

[98] See Genebank Standards (Standard 4.9.1): http://www.fao.org/3/a-i3704e.pdf

- placing an outer and inner label for each packet to ensure that the material is properly identified.

✓ **The choice of packaging and transport allows for safe and timely delivery.**
Ensure that the material reaches the destination genebank in good condition considering 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 and distribution is recommended.

✓ **Each safety duplicate sample is accompanied by relevant associated information.**[99]
It is recommended to include minimum information along with the shipment, including an itemized list with accession identification, key passport data, total amount of seeds (by weight or number), type of container, etc. Information may be electronically transferred, as well as printed.

✓ **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, seed number per sample, packaging information, shipping log, reference to legal agreement, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

✓ **The genebank information management system is regularly checked/compared to ensure that any new material not duplicated in the recipient genebank is identified and prepared for safety duplication, as appropriate.**

[99] See Genebank Standards (Standard 4.9.2): http://www.fao.org/3/a-i3704e.pdf

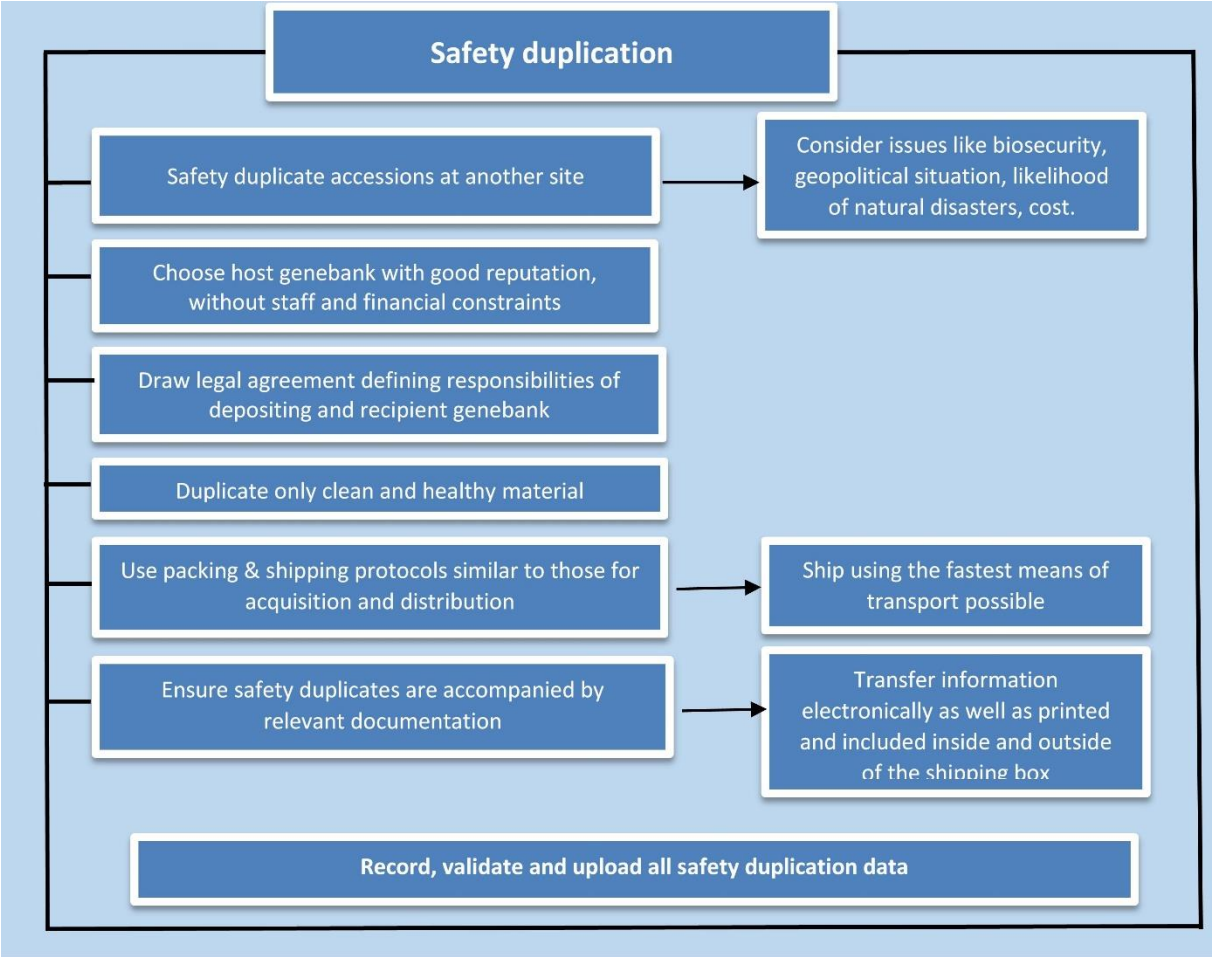

Figure 11. Flow diagram for safety duplication of germplasm

11. Personnel and Security

Personnel:

It is recommended that the genebank has a strategy in place for personnel, including a succession plan, and a corresponding budget must be allocated regularly.

✓ **The genebank has a human resource plan with appropriate annual budget allocation and staff have the critical skills, experience and qualifications required 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.[100] 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;
- 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 the latest developments;
- rotating tasks to make work as varied as possible and involve all staff (where possible) in meetings and discussions;
- retaining competent staff by providing recognition and rewards for excellent performance;
- crop groups specific curators including technical support staff with knowledge and skills in agriculture, horticulture and taxonomy of cultivated plants and their wild relatives is essential, and
- having access to disciplinary and technical specialists in a range of subject areas, such as physiology, phytopathology, is desirable.

✓ **Risks associated with staffing are included in the risk identification, analysis and management.**

Secure conservation depends on an 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 *inter alia* measures to deal with power cut, fire, flooding, earthquakes, war and civil strife.[101] This strategy and an accompanying action plan is 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: [102]

- *Communication and consultation* to 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* to consider the objectives/activities/tasks of the genebank, the environment in which the activities operate, and the stakeholders;
- *Risk identification* involves carrying out an inventory of relevant risks to the genebank operations;

[100] See Genebank Standards (Standard 4.10.3): http://www.fao.org/3/a-i3704e.pdf
[101] See Genebank Standards (Standard 4.10.1): http://www.fao.org/3/a-i3704e.pdf
[102] https://cropgenebank.sgrp.cgiar.org/index.php/management-mainmenu-433/risk-management-mainmenu-236

- *Risk analysis* involves carrying out an analysis of potential impact (or consequence) of the identified risks and their likelihood (probability);
- *Risk evaluation* to determine the level of risk that is acceptable;
- *Risk treatment* to identify the course of action to deal with those risks where the current total risk rating is considered unacceptable, giving top priority to the highest assessed residual risks; and
- *Monitoring and review* to analyze 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.**

Occupational safety and health (OSH) deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards.[103] Most countries will have an OSH policy. The International Labour Organization (ILO)[104] 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 are 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 lab environments;
- choosing appropriate and nationally approved agrochemicals to reduce risk; and
- providing properly functioning protective equipment and clothing, as required by OSH, and ensuring it is regularly checked and used in the field. The OSH officer is responsible for safety equipment upkeep.

[103] See Genebank Standards (Standard 4.10.2): http://www.fao.org/3/a-i3704e.pdf

[104] https://www.ilo.org/global/lang--en/index.htm

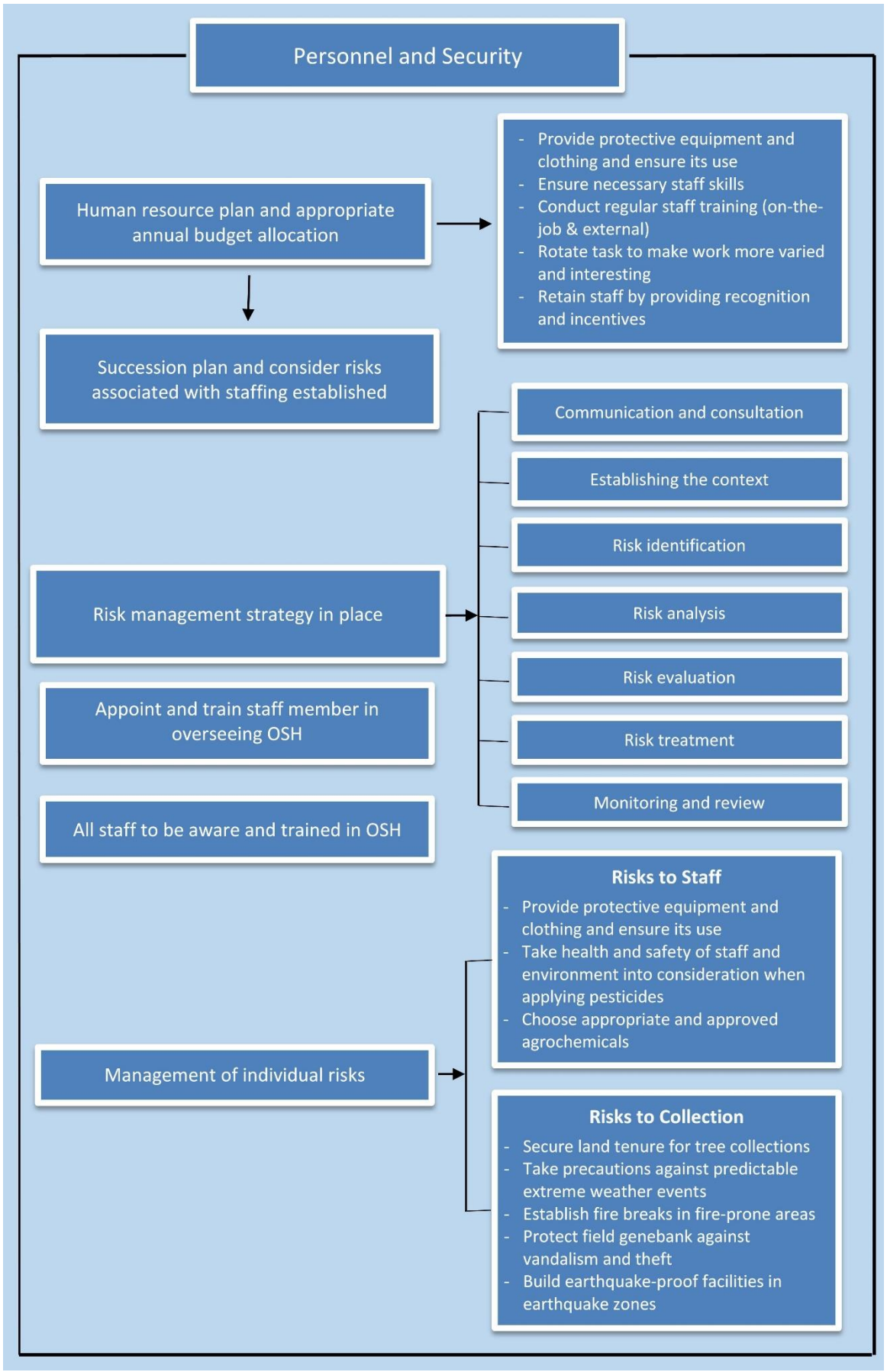

Figure 12. Summary diagram for Personnel and Security

12. Infrastructure and Equipment

This section considers the suggested infrastructure and equipment for a seed genebank. The long-term storage of orthodox seeds is based upon reduction of seed moisture content followed by hermetic storage at low temperature. The seedbank infrastructure is therefore centered around seed drying and storage facilities, integrated 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 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 qualified staff.

A useful case study from India calculated the costs of establishing seed bank facilities, and acquiring, processing, storing (medium and long-term), monitoring and regenerating germplasm.[105] The Millennium Seed Bank series of technical information sheets provide helpful background and a list of equipment specifications for key seedbank activities and areas.[106] 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 and deep freezers.

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

Genebank Operation/Management Area
General needs
Office space and supplies; computers, printers and accessories; climate data loggers; mobile devices for electronic data recording and bar code readers; access to scientific and technical literature; Internet access.
Acquisition
Collecting equipment including cloth and/or paper bags, labels (ideally bar-coded), hand lens, scissors, tarpaulins, packaging materials, herbarium presses¸ simple desiccation drier.
Collecting data sheets or mobile devices for electronic data recording, GPS or altimeter, expedition equipment for collecting missions.
Drying and Storage
Dry room and associated plant room and/or other appropriate drying facilities, digital humidity sensor or other means of measuring moisture status.
Hermetic containers or tri-laminate foil bags/bag sealer for long-term storage, air tight easily opened containers for medium-term storage, labels (ideally bar-coded), balances, seed counter, data sheets or mobile devices for electronic data recording, bar code reader.
Cold room(s) including plant room for refrigeration equipment and shelving system and/or refrigerators, thermostat, low temperature alarm, personnel panic button.
Seed Viability Monitoring
Germination test facilities including media preparation area, test set-up/scoring area, dissection equipment, microscopes, controlled environment facility (plant growth room,

[105] Singh, A.K., Varaprasad, K.S. & Venkateswaran, K. 2012. Conservation Costs of Plant Genetic Resources for Food and Agriculture: Seed Genebanks. Agricultural Research, 1(3): 223–239. https://doi.org/10.1007/s40003-012-0029-3

[106] https://www.kew.org/science/collections/seed-collection/millennium-seed-bank-resources

germination chamber, incubator), viability test sheets, data sheets or mobile devices for electronic data recording, bar code reader.
Regeneration
Access to field or glasshouse areas as required. Isolations tents; overwintering storage for biennial vegetables; fenced area for perennial nurseries. Insect rearing gear/incubators as required. Growth chambers if required for quarantine. Field/glasshouse equipment and machinery as necessary, according to species. Plot stakes and labels (ideally bar-coded), labelled cloth bags or other appropriate containers. Data sheets or mobile devices for electronic data recording, bar code reader.
Characterization
Access to field, lab or glasshouse areas as required. Field/lab/glasshouse equipment and machinery as necessary, according to species and traits being recorded. Plot stakes and labels (ideally bar-coded), labelled cloth bags or other appropriate containers. Data sheets or mobile devices for electronic data recording, bar code reader.
Evaluation
Access to field areas in different agro-ecological zones. Access to glasshouse areas as required. Field/lab/glasshouse equipment and machinery as necessary, according to species and traits being recorded. Plot stakes and labels (ideally bar-coded), labelled cloth bags or other appropriate containers. Data sheets or mobile devices for electronic data recording, bar code reader.
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 viability monitoring tools, seed quantity and distribution tracker is optimal.
Distribution and Exchange
Sample packets, labels (preferably barcoded), packaging materials. Data sheets or mobile devices for electronic data recording, bar code reader.
Safety Duplication
Balances, seed counter, tri-laminate foil bags, bag sealer, labels (preferably barcoded), packaging materials. Data sheets or mobile devices for electronic data recording, bar code reader.

Security and Personnel
Generator(s), fire extinction equipment, security cameras, alarm systems, security doors.
Protective clothing

13. Further Information/Reading

The list of references below provide 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*.[107]

General References

Anonymous. undated. *International Treaty on Plant Genetic Resources for Food and Agriculture|Food and Agriculture Organization of the United Nations*. http://www.fao.org/plant-treaty/en/

Ellis, R.H., Hong, T.D. & Roberts, E.H. 1985. *Handbook of seed technology for genebanks*. https://www.bioversityinternational.org/e-library/publications/detail/handbook-of-seed-technology-for-genebanks-1/

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. IPGRI handbooks for genebanks No. 6. Rome, IPGRI. 165 pp. https://www.bioversityinternational.org/e-library/publications/detail/a-guide-to-effective-management-of-germplasm-collections/

FAO. 2014. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rome. http://www.fao.org/3/a-i3704e.pdf

Greene, S.L., Williams, K.A., Khoury, C.K., Kantar, M.B., & Marek, L.F. 2018. *North American Crop Wild Relatives, Volume 1*. Springer Nature Switzerland AG. https://link.springer.com/content/pdf/10.1007%2F978-3-319-95101-0.pdf

IPK Gatersleben. undated. *Mansfeld's World Database of Agriculture and Horticultural Crops*. http://mansfeld.ipk-gatersleben.de/apex/f?p=185:3

Rao, N.K, Hanson, J, Dulloo, M.E, Ghosh, K., Nowell, A. & Larinde, M. 2006. *Manual of seed handling in genebanks*. https://www.bioversityinternational.org/e-library/publications/detail/manual-of-seed-handling-in-genebanks/

Upadhyaya, H.D. & Gowda, C.L. 2009. *Managing and Enhancing the Use of Germplasm – Strategies and Methodologies*. http://genebank.icrisat.org/PDF/Section/Section4,5.pdf

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

USDA/ARS. undated. *Taxonomic Information on Cultivated Plants in GRIN-Global*. https://npgsweb.ars-grin.gov/gringlobal/taxon/abouttaxonomy.aspx

Acquisition and Distribution

Alercia, A; Diulgheroff, S; Mackay, M. 2015. *FAO/Bioversity Multi-Crop Passport Descriptors V.2.1 [MCPD V.2.1]*. Rome: FAO and Bioversity International, 11 p. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/FAOBIOVERSITY_MULTI-CROP_PASSPORT_DESCRIPTORS_V.2.1_2015_2020.pdf

[107] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf

Bioversity 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). https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. *Handbooks for Genebanks No. 6*. Rome, IPGRI. https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/A_guide_to_effective_management_of_germplasm_collections_899.pdf

ENSCONET. 2009. *Seed collecting manual for wild species*. http://www.plants2020.net/document/0183/

Eymann, J., Degreef, J., HŠuser, C., Monje, J.C., Samyn, Y. & VandenSpiegel, D., eds. 2010. *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring, Vol. 8.* http://www.abctaxa.be/volumes/volume-8-manual-atbi

Greiber, T., Peña Moreno, S., Ahrén, M., Nieto Carrasco, J., Kamau, E.C., Cabrera Medaglia, J., Oliva, M.J., & Perron-Welch, F. (in cooperation with Ali, N., Williams, C.). 2012. *An Explanatory Guide to the Nagoya Protocol on Access and Benefit-sharing*. IUCN, Gland, Switzerland. xviii + 372 pp. https://cmsdata.iucn.org/downloads/an_explanatory_guide_to_the_nagoya_protocol.pdf

Guarino, L.G., Rao, L.R. & Reid, V. 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB international. https://www.bioversityinternational.org/e-library/publications/detail/collecting-plant-genetic-diversity/

Hay, F.R. & Probert, R.J. 2011. *Collecting and handling seeds in the field*. In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=655

IRRI. undated. *TRANSFER of Plant Genetic Resources for Food and Agriculture*. In: Crop Genebank Knowledge Base. http://www.knowledgebank.irri.org/smta/

Lopez, F. 2015. Digital Object Identifiers (DOIs) in the context of the International Treaty. http://www.fao.org/fileadmin/templates/agns/WGS/10_FAO_gs_activities_ITPGRFA_20151207.pdf

Mathur, S.B. & Kongsdal, O. 2003. *Common laboratory seed health testing methods for detecting fungi*. Bassersdorf, Switzerland.

Maya-Lastra, C.A. 2016. ColectoR, a digital field notebook for voucher specimen collection for smartphones. *Applications in Plant Sciences*, 4(7). https://doi.org/10.3732/apps.1600035

Moore, G. & Williams, K.A. 2011. *Legal issues in plant germplasm collecting* In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=669

Ni, K.J. 2009. Legal aspects of prior informed consent on access to genetic resources: An analysis of global law-making and local implementation toward an optimal normative construction. *Journal of Transnational Law*, 42, p.227.

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 02. Assessing a population for seed collection.* http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/02-Assessing-population.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 03. Seed collecting techniques*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/03-Collecting-techniques.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 04. Post harvest handling*. http://www.anayglorious.in/sites/default/files/04-Post%20harvest%20handling%20web_0.pdf

Smith, R.D., Dickie, J.B., Linington, S.H., Pritchard, H.W. & Probert, R.J., eds. 2003. *Seed conservation: turning science into practice*. Kew, UK, Royal Botanic Gardens

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

Way, M. 2003**.** Collecting Seed from Non-domesticated Plants for Long-Term Conservation. In: R.D. Smith, J.D. Dickie, S.H. Linington, H.W. Pritchard and R.J. Probert (eds.), *Seed Conservation: turning science into practice*. Royal Botanic Gardens, Kew, UK. pp. 163-201.

Way, M. 2011. Crop Genebank Knowledge Base. *Collecting and recording data in the field: media for data recording*. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=659

Drying and Storage

Ellis, R.H. 1991. The Longevity of Seeds. *HortScience*, 26: 1119–1125. http://hortsci.ashspublications.org/content/26/9/1119.full.pdf

Ellis, R.H. & Hong, T.D. 2006. Temperature sensitivity of the low-moisture-content limit to Negative Seed Longevity–Moisture Content Relationships in Hermetic Storage. *Annals of Botany*, 97(5): 785–791. https://doi.org/10.1093/aob/mcl035

Ellis, R.H. & Hong, T.D. (2007) Quantitative response of the longevity of seed of twelve crops to temperature and moisture in hermetic storage. *Seed Science and Technology*, 35, 432-444.

Ellis, R.H., Hong, T.D. & Roberts, E.H. 1985. Sequential germination test plans and summary of preferred germination test procedures. *Handbook of seed technology for genebanks. Vol I . Principles and methodology*. Chapter 15, pp. 179–206. Rome, IBPGR. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/52.pdf

Pérez-García, F., Gómez-Campo, C. & Ellis, R.H. 2009. Successful long-term ultra-dry storage of seed of 15 species of *Brassicaceae* in a genebank: variation in ability to germinate over 40 years and dormancy. *Seed Science and Technology*, 37(3): 640–649. https://doi.org/10.15258/sst.2009.37.3.12

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 06. Selecting containers for long-term seed storage*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/06-Containers.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 07. Low cost moisture monitors*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/07-Low-cost-moisture-monitors.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 08. Small-scale drying methods*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/08-Small-scale-drying-methods.pdf

Whitehouse, K.J., Hay, F.R. & Ellis, R.H. 2015. Increases in the longevity of desiccation-phase developing rice seeds: response to high-temperature drying depends on harvest moisture content. *Annals of Botany*, 116(2): 247–259. https://doi.org/10.1093/aob/mcv091

Viability Monitoring

AOSA (Association of Official Seed Analysts). 2016. *AOSA Rules for Testing Seeds. Volume1 Principles and Procedures*. http://www.agriculture.ks.gov/docs/default-source/public-comment-on-proposed-regulations/docs-adopted-for-kar-4-2-8/volume-1---aosa-rules-for-testing-seeds.pdf?sfvrsn=4

AOSA (Association of Official Seed Analysts) and SCST (Society of Commercial Seed Technologists). undated. Test Methods for Species without Rules. https://www.analyzeseeds.com/test-methods-for-species-without-rules/

Ellis, R.H., Nasehzadeh, M., Hanson, J. & Woldemariam, Y. 2017. Medium-term seed storage of 50 genera of forage legumes and evidence-based genebank monitoring intervals. *Genetic Resources and Crop Evolution*: 1–17. https://doi.org/10.1007/s10722-017-0558-5

ENSCONET. 2009. *ENSCONET Curation Protocols & Recommendations*. http://ensconet.maich.gr/PDF/Curation_protocol_English.pdf

ENSCONET. 2009. *ENSCONET Germination Recommendations UPDATED*. http://ensconet.maich.gr/PDF/Germination_recommendations_English.pdf

Hay, F.R., Mead A., Manger, K. & Wilson F.J., (2003), One-step analysis of seed storage data and the longevity of *Arabidopsis thaliana* seeds, *Journal of Experimental Botany* 54 (384), 993-1011

Hay, F.R. & Probert, R.J. 2013. Advances in seed conservation of wild plant species: a review of recent research. *Conservation Physiology*, 1(1). https://doi.org/10.1093/conphys/cot030

Hay, F.R. & Whitehouse, K.J. 2017. Rethinking the approach to viability monitoring in seed genebanks. *Conservation Physiology*, 5(1). https://doi.org/10.1093/conphys/cox009

ISTA (International Seed Testing Association). 2018. *International Rules for Seed Testing 2018*. https://www.seedtest.org/en/international-rules-_content---1--1083.html

Nagel, M., Rehman Arif, M.A., Rosenhauer, M. & Börner, A. 2010. *Longevity of seeds – intraspecific di.erences in the Gatersleben genebank collections*. Tagungsband der 60. Jahrestagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2009, 179–181. http://www.ecpgr.cgiar.org/fileadmin/templates/ecpgr.org/upload/NW_and_WG_UPLOADS/Wheat_Misc/GUMP_NAGEL_2010.pdf

Mondoni, A., Probert, R.J., Rossi, G., Vegini, E. & Hay, F.R. 2011. Seeds of alpine plants are short lived: implications for long-term conservation. *Annals of Botany*, 107(1): 171–179. https://doi.org/10.1093/aob/mcq222

Probert, R.J., Daws, M.I. & Hay, F.R. 2009. Ecological correlates of ex situ seed longevity: a comparative study on 195 species. *Annals of Botany*, 104(1): 57–69. https://doi.org/10.1093/aob/mcp082

Royal Botanic Gardens, Kew. 2018. *Seed Information Database (SID). Version 7.1*. http://data.kew.org/sid/

Royal Botanic Gardens, Kew. 2015. *Technical Information Sheet_13a. Germination testing: procedures and evaluation*.

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

Royal Botanic Gardens, Kew. 2015. *Technical Information Sheet_13b. Germination testing: environmental factors and dormancy-breaking treatments*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/13b-Germination-testing-dormancy.pdf

Royal Botanic Gardens, Kew. undated. *Seed Information Database: Seed Viability*. http://data.kew.org/sid/viability/

Santos, L.G. 2017. Sequential Sampling for Seed Viability Testing at CIAT's Genebank. Paper presented at, 22 May 2017, Ethiopia. https://cgspace.cgiar.org/bitstream/handle/10568/89648/SEEDS_SEQUENTIAL_SAMPLING_ETHIOPIA_May-22-2017.pdf?sequence=1

Walters, C., Wheeler, L.M. & Grotenhuis, J.M. 2005. Longevity of seeds stored in a genebank: species characteristics. *Seed Science Research*, 15(1): 1–20. https://doi.org/10.1079/SSR2004195

Regeneration

Ahuja, M.R. & Jain, S.M. 2015. *Genetic Diversity and Erosion in Plants: Indicators and Prevention*. Springer. 327 pp.

Breese, E.L. 1989. *Regeneration and multiplication of germplasm resources in seed genebanks: the scientific background*. Rome, IBPGR. http://www.bioversityinternational.org/fileadmin/bioversity/publications/Web_version/209/begin.htm

Crossa, J. 1995. Sample size and effective population size in seed regeneration of monecious species. *In* J.M.M. Engels & R. Rao, eds. *Regeneration of seed crops and their wild relatives*, pp. 140–143. Proceedings of a consultation meeting, 4–7 December 1995. Hyderabad, India, ICRISAT, and Rome, IPGRI. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/regeneration_seed_crops.pdf

Crossa, J. & Vencovsky, R. 2011. Basic sampling strategies: theory and practice. In: *Crop Genebank Knowledge Base*. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=671

Dulloo, M.E., Hanson, J., Jorge, M.A. & Thormann, I. 2008. *Regeneration guidelines: General guiding principles*. https://cropgenebank.sgrp.cgiar.org/images/file/other_crops/Introduction_ENG.pdf

Engels, J.M.M. & Rao, R., eds. 1995. *Regeneration of seed crops and their wild relatives*, pp. 140–143. Proceedings of a consultation meeting, 4-7 December 1995. Hyderabad, India, ICRISAT, and Rome, IPGRI.

ICRISAT. *Germplasm regeneration*. http://www.icrisat.org/what-we-do/genebank/genebank-manual/germplasm-regeneration-9.pdf

Jorge, M.A. 2009. Introduction to guidelines on regeneration of accessions in genebanks. Paper presented at International Course on Plant Genetic Resources and Genebank Management, 2009, Suwon, Korea. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/korea_workshop/lecture1and2/Lecture%202%20-%20regeneration%20guidelines.pdf

Sackville Hamilton, N.R & Chorlton, K.H. 1997. *Regeneration of accessions in seed collections: A decision guide*. https://www.bioversityinternational.org/e-library/publications/detail/regeneration-of-accessions-in-seed-collections/

Characterization and Evaluation

Alercia, A. 2011. *Key characterization and evaluation descriptors: methodologies for the assessment of 22 crops*. Bioversity International 602 p. https://cgspace.cgiar.org/handle/10568/74491

Bioversity International. 2007. *Bioversity Technical Bulletin No. 13: Developing crop descriptor lists. Guidelines for developers.* https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1[news]=1053&cHash=03f5fd26b4bf10a47e6e0ca712ac4610

Bioversity International. undated. *Descriptors*. https://www.bioversityinternational.org/e-library/publications/descriptors/

Bioversity International. 2018. *Crop descriptors and derived standards*. https://www.bioversityinternational.org/fileadmin/user_upload/about_us/news/publications/List_of_Descriptors_Titles_2018.pdf

FAO. 2011. *Pre-breeding for Effective Use of Plant Genetic Resources*. http://www.fao.org/elearning/#/elc/en/course/PB

Lehmann C. and Mansfeld R. 1957 Zur Technik der Sortimentserhaltung. *Die Kulturpflanze* 5, 108–138.

Thormann, I., Parra-Quijano, M., Endresen, D.T.F., Rubio-Teso, M.L., Iriondo, M.J. & Maxted, N. 2014. *Predictive characterization of crop wild relatives and landraces Technical guidelines version 1.* https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Predictive_characterization_guidelines_1840.pdf

Thormann, I. 2015. Predictive characterization: an introduction. Paper presented at Regional Training Workshop, 13 April 2015, Pretoria, South Africa. http://www.cropwildrelatives.org/fileadmin/templates/cropwildrelatives.org/upload/sadc/project_meetings/Lectures_Predictive_characterization_pre-breeding/Introduction_Predictive_Characaterization_Thormann.pdf

UPOV. undated. *Test Guidelines*. http://www.upov.int/test_guidelines/en/

Molecular Characterization and Evaluation

Arif, I.A., Bakir, M.A., Khan, H.A., Al Farhan, A.H., Al Homaidan, A.A., Bahkali, A.H., Sadoon, M.A. & Shobrak, M. 2010. A Brief Review of Molecular Techniques to Assess Plant Diversity. *International Journal of Molecular Sciences*, 11(5): 2079–2096. https://doi.org/10.3390/ijms11052079

Ayad, W.G., Hodgkin, T., Jaradat, A. & Rao, V.R. 1997. *Molecular genetic techniques for plant genetic resources*. Report on an IPGRI workshop, 9–11 October 1995, Rome, Italy. Rome, Italy, IPGRI, 137 p. http://www.bioversityinternational.org/fileadmin/bioversity/publications/Web_version/675/begin.htm

Bretting, P.K. & Widrlechner, M.P. 1995. Genetic markers and plant genetic resource management. *Plant Breeding Reviews*, 13:11–86.

D'Agostino, N. & Tripodi, P. 2017. NGS-Based Genotyping, High-Throughput Phenotyping and Genome-Wide Association Studies Laid the Foundations for Next-Generation Breeding in Horticultural Crops. *Diversity*, 9(3): 38. https://doi.org/10.3390/d9030038

de Vicente, M.C. & Fulton, T. 2004. *Using molecular marker technology in studies on plant genetic diversity*. Rome, Italy, IPGRI, and Ithaca, New York, USA, Institute for Genetic Diversity. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Molecular_Markers_Volume_1_en.pdf

de Vicente, M.C., Metz, T. & Alercia, A. 2004. *Descriptors for genetic markers technologies*. https://www.bioversityinternational.org/e-library/publications/detail/descriptors-for-genetic-markers-technologies/

Govindaraj, M., Vetriventhan, M. & Srinivasan, M. 2015. Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances: An Overview of Its Analytical Perspectives. In: *Genetics Research International*. https://www.hindawi.com/journals/gri/2015/431487/

Jia, J., Li, H., Zhang, X., Li, Z. & Qiu, L. 2017. Genomics-based plant germplasm research (GPGR). *The Crop Journal*, 5(2): 166–174. https://doi.org/10.1016/j.cj.2016.10.006

Jiang, G.-L. 2013. Molecular Markers and Marker-Assisted Breeding in Plants. In: Andersen, S.B. *Plant Breeding from Laboratories to Fields*. IntechOpen, Denmark. https://doi.org/10.5772/52583

Karp, A., Kresovich, S., Bhat, K.V., Ayad, W.G. & Hodgkin, T. 1997. *Molecular tools in plant genetic resources conservation: a guide to the technologies*. IPGRI Technical Bulletin No. 2. Rome, IPGRI.

Keilwagen, J., Kilian, B., Özkan, H., Babben, S., Perovic, D., Mayer, K.F.X., Walther, A., Poskar, C.H., Ordon, F., Eversole, K., Börner, A., Ganal, M., Knüpffer, H., Graner, A. & Friedel, S. 2014. Separating the wheat from the chaff – a strategy to utilize plant genetic resources from *ex situ* genebanks. *Scientific Reports*, 4: 5231. https://doi.org/10.1038/srep05231

Kilian, B. & Graner, A. 2012. NGS technologies for analyzing germplasm diversity in genebanks. *Briefings in Functional Genomics*, 11(1): 38–50. https://doi.org/10.1093/bfgp/elr046

Laucou, V., Lacombe, T., Dechesne, F., Siret, R., Bruno, J.P., Dessup, M., Dessup, P., Ortigosa, P., Parra, P., Roux, C., Santoni, S., Varès, D., Perós, J.P., Boursiquot, J.M. & This, P. 2011. High throughput analysis of grape genetic diversity as a tool for germplasm collection management. *Theoretical and Applied Genetics*, 122(6): 1233–1245.

Mishra, K.K., Fougat, R.S., Ballani, A., Thakur, V., Jha, Y. & Madhumati, B. 2014. Potential and application of molecular markers techniques for plant genome analysis. *International Journal of Pure & Applied Bioscience*, 2(1): 169–188.

van Treuren, R. & van Hintum, T. 2014. Next-generation genebanking: Plant genetic resources management and utilization in the sequencing era. *Plant Genetic Resources*, 12(3): 298–307.

Documentation

Ougham, H. and Thomas, I.D., 2014. *Germplasm databases and informatics. Plant Genetic Resources and Climate Change*, pp.151-165. CAB International, CPI Group, UK.

Painting, K.A, Perry, M.C, Denning, R.A. & Ayad, W.G. 1993. *Guidebook for genetic resources documentation*. Rome, Italy, IPGRI. https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Guidebook_for_genetic_resources_documentation_432.pdf

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

Bretting P.K. 2018. 2017 Frank Meyer Medal for Plant Genetic Resources Lecture: Stewards of Our Agricultural Future. Vol. 58 No. 6, p. 2233-2240.

Fu, Y.-B. 2017. The vulnerability of plant genetic resources conserved *ex situ*. *Crop Science*, 57(5): 2314. https://doi.org/10.2135/cropsci2017.01.0014

Linington, S.H. 2003. The design of seed banks. In: R.D. Smith, J.B. Dickie, S.H. Linington, H.W. Pritchard and R.J. Probert (eds.), *Seed Conservation: turning science into practice*. Royal Botanic Gardens, Kew, UK.

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 04. Post-harvest handling*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/04-Post-harvest-handling.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 05. Measuring seed moisture status using a hygrometer*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/05-eRH-moisture-measurement.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 06. Selecting containers for long-term seed storage*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/05-eRH-moisture-measurement.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 07. Low-cost monitors of seed moisture status*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/07-Low-cost-moisture-monitors.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 08. Small-scale seed drying methods.* http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/08-Small-scale-drying-methods.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 11. Seed bank design: seed drying rooms*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/11-Seed-drying-room-design.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 12. Seed bank design: cold rooms for seed storage*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/12-Cold-room-design.pdf

Royal Botanic Gardens, Kew. 2015. *Millennium Seed Bank technical information sheet_13a. Germination testing: procedures and evaluation*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/13a-Germination-testing-procedures.pdf

Royal Botanic Gardens, Kew. 2015. *Millennium Seed Bank technical information sheet_13b. Germination testing: environmental factors and dormancy-breaking treatments*.

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

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 14. Cleaning seed collections for long-term conservation.* http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/14-Seed-cleaning.pdf

Singh, A.K., Varaprasad, K.S. & Venkateswaran, K. 2012. Conservation Costs of Plant Genetic Resources for Food and Agriculture: Seed Genebanks. *Agricultural Research*, 1(3): 223–239. https://doi.org/10.1007/s40003-012-0029-3

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 during genebank operations to be considered are presented below.

Acquisition

Risk	Risk Control/Mitigation
Diversity of the source population is not adequately represented in the collected sample	Develop and follow agreed collecting plan
Taxonomic misidentification	Include taxonomist in collecting team and hire genebank staff trained in taxonomy Take herbarium vouchers and photos for verification by experts
Mislabeling/loss of labels	Firmly attach one label to collecting bag; include another label inside the collecting bag
Transcription errors	Consider use of mobile devices Data validation
Loss of viability during collecting missions/transport leading to reduced seed longevity (and earlier regeneration)	Timely transfer to controlled drying conditions Appropriate post-harvest handling according to maturity of seeds and prevailing environmental conditions

Drying and Storage

Risk	Risk Control/Mitigation
Reduced seed longevity due to moisture during packaging	Package seeds in controlled, dry environment
Reduced seed longevity and earlier regeneration due to container leakage	Leak-test every new batch of packaging material. Ensure sealing machine is working properly Ensure screw caps are adequately tightened Set up a monitoring system to periodically measure the eRH of randomly selected collections from the genebank, and of any accessions removed for testing or distribution
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Stored sample falls below viability or quantity thresholds	Ensure that documentation system includes automated tools to monitor seed viability and seed inventory and flag up accessions requiring regeneration
Inadequate storage temperature due to power failure	Backup generators and fuel available

Seed Viability Monitoring

Risk	Risk Control/Mitigation
True viability of the accession is not reflected during germination testing	Optimize germination testing and dormancy breaking methods. Use data on firm/fresh seeds to estimate viability of dormant accessions Randomized evaluation of germination tests. Out-sourcing of germination testing if necessary
Inappropriate viability testing intervals	Use all available information, for example, germination rate, and number of abnormal seedlings, to better understand how quickly a particular accession is aging and tailor monitoring intervals appropriately

Regeneration

Risk	Risk Control/Mitigation
Loss of adaptive alleles due to selection pressures	Regenerate under controlled environmental conditions Regenerate at other sites 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. Hand pollinate as required/possible
Misidentification of sample	Check plot and bag labels prior to sowing and harvesting; use bar codes
Loss of purity due to due to contamination/mixing of seed samples during seed preparation, sowing, harvesting and post-harvest handling	Careful inspection and cleaning of all machinery between each processing step

Characterization

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Appropriate cultural practices Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Use of check accessions/varieties Check plot labels while collecting data Check plot and bag labels prior to sowing and harvesting

Evaluation

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Appropriate statistical design Selection of appropriate locations for planting Appropriate cultural practices Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Use of check accessions/varieties Check plot labels while collecting data Check plot and bag labels prior to sowing and harvesting

Distribution

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Include viability monitoring samples and agree whether these will be tested by recipient or returned to sending institution

Safety duplication

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Include viability monitoring samples and agree whether these will be tested by recipient or returned to sending institution

ANNEX 2. Draft Practical Guide for the Application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture

Conservation in Field Genebanks

Table of Contents

1. Introduction

Many field and horticultural crops as well as agroforestry species are difficult or impossible to preserve as seeds as they are only producing recalcitrant seeds with a short life span in seed storage, seed production might take many years as is the case for many tree species, or they do not produce seeds at all and can only be vegetatively propagated. Major crop groups kept in field genebanks include: root and tuber crops such as potato, cassava, yams, sweet potato, taro and bananas; sub-tropical 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). Although some of the crops conserved in this way are sexually fertile, it is often not convenient to propagate them commercially from seed because of high levels of 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, is essential to maintain plants free of diseases. However, field genebanks provide ready and easy access to the conserved material for characterization, evaluation and research, in general, but also to germplasm users who can visit the collections and inspect the plants during vegetative or reproductive stages to have a first visual impression. Vegetative materials are readily available for germplasm distribution.

Conservation in field genebanks can be broken down into a process of interrelated operations (Figure 1). This practical guide for the conservation in field genebanks suggests practices and activities critical to the underlying genebank principles in each operational area (Table 1). It outlines workflows for routine genebank operations for conservation in field genebanks (Figure 2), and supports the application of the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (Genebank Standards).[108] The purpose of this guide is to present the information contained in the Genebank Standards in a more user-friendly format detailing the different actions of the genebank workflow in a sequential manner and facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis to develop Standard Operating Procedures (SOPs)[109] and Quality Management Systems[110] for conserving these germplasm collections, defining in detail how to carry out each activity.

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

[108] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf

[109] 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

[110] https://www.genebanks.org/the-platform/quality-management/

Figure 1. Major operations for conservation in field genebanks

Table 1: The underlying principles and related genebank operations for field genebanks

Genebank principle	Summarized genebank operations
Identity of accessions	Passport data collected and recorded Botanical identification verified Permanent and unique accession number assigned and used in all documentation Labelling & tracking in genebank Careful processing undertaken
Maintenance of viability	Best practices followed when collecting, processing, field introduction and cultural practices, regenerating, and transporting Field conditions optimized and monitored Regeneration undertaken when necessary
Maintenance of genetic integrity	Collecting and maintenance of samples conducted in a manner that ensures they represent original population Field site in location that minimises gene flow and genetic contamination Best practices followed when collecting, processing, field introduction and cultural practices, regenerating, and transporting
Maintenance of germplasm health	Quarantine procedures undertaken when/if needed Best practices followed when collecting, processing, field introduction and management practices, growing, regenerating, and transporting Pests and diseases monitored and managed
Physical security of collections	Risk management strategy developed and implemented Accessions safety duplicated/safety backed-up Field site in secure location Appropriate genebank infrastructure in place and maintained
Availability and use of germplasm	Germplasm acquired and distributed according to legal and phytosanitary requirements Sufficient stocks, efficient and timely transfer & systems in place to support use of germplasm Relevant documentation provided to recipients of genebank material
Availability of information	Functional genebank information management system in place Passport and accession management data secured by regular data backups Passport and other relevant data available and accessible
Proactive management of genebanks	Standards of Operation developed and available to staff Data and information generated during genebank activities available to managers Well-trained staff employed and protected by Occupational Safety and Health measures Genebank staff capacities kept current and trainings provided as necessary

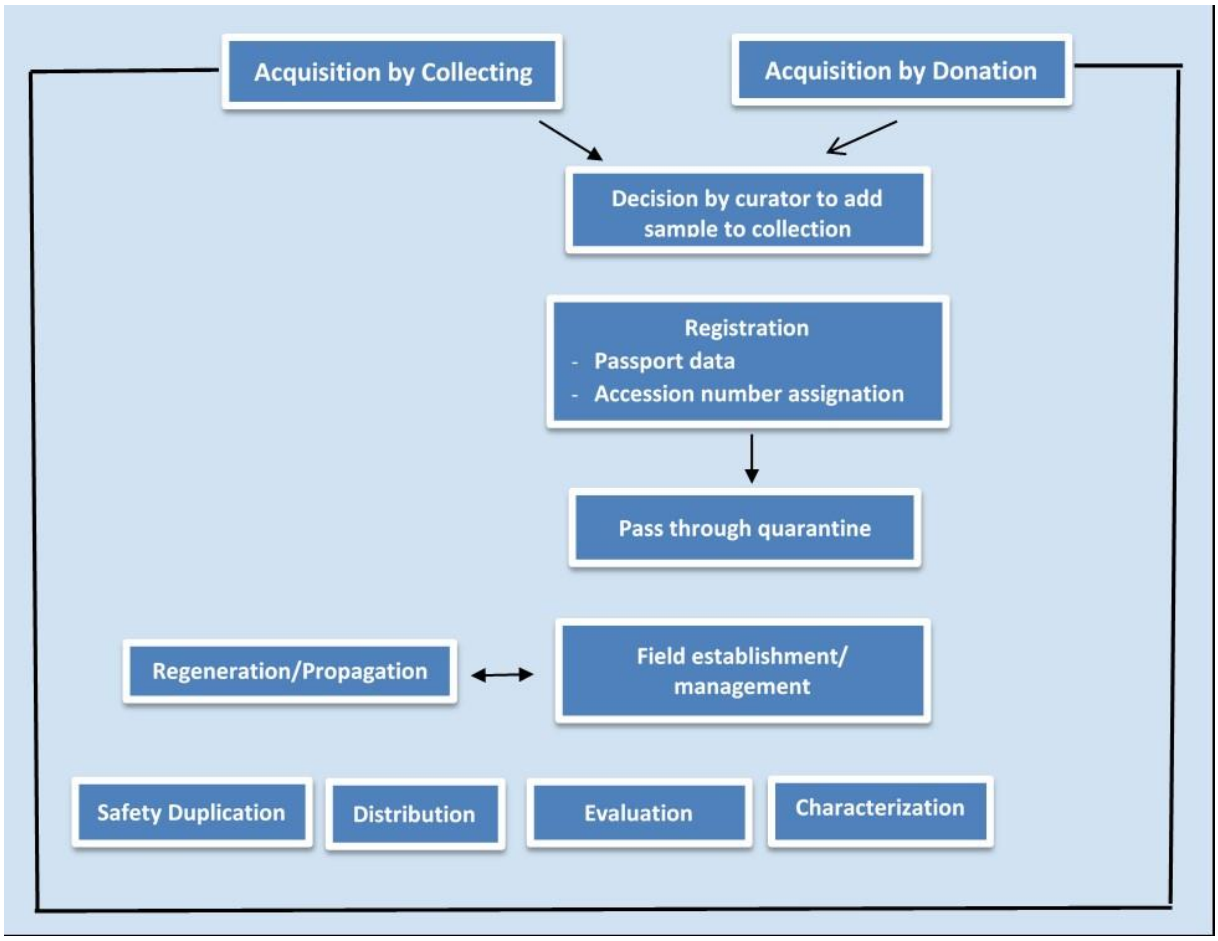

Figure 2. Flow of germplasm in a genebank for conservation in field genebanks. Each step is associated with proper documentation

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.**[111]

It is important to choose a field site with optimum climate, elevation and soil conditions to provide appropriate to optimum conditions for good adaptation and growth of plants. This will minimize the risk of plant losses due to poor adaptation of material, which originated in environments quite different from that of the genebank location.

✓ **The site is in a location that minimises risks from natural and manmade disasters.**[112]

Safety of the collection is a priority of every genebank. It is necessary to undertake a risk assessment to ensure that natural and manmade 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 and/or known to have civil strife; and
- Choosing a location where the target crop has not been grown previously 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 or gazetted land tenure.**[113]

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.

✓ **The site provides sufficient space for future expansion as new accessions might need to be added after a couple of years of establishment of the field genebank, if possible.**

✓ **The site is within easy reach for curational staff and field labourers through transport.**[114]

Easy physical access to the field genebank site facilitates field and plant management as well as regular monitoring.

✓ **The land area selected for the field genebank is suitable for using machinery for mulching, fertilizer and pesticide applications.**

✓ **The site has easy access to a water source for pesticide applications and supplemental irrigation as required.**

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

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[111] See Genebank Standards (Standard 5.1.1): http://www.fao.org/3/a-i3704e.pdf
[112] See Genebank Standards (Standard 5.1.2): http://www.fao.org/3/a-i3704e.pdf
[113] See Genebank Standards (Standard 5.1.4): http://www.fao.org/3/a-i3704e.pdf
[114] See Genebank Standards (Standard 5.1.5): http://www.fao.org/3/a-i3704e.pdf

- ✓ **The site minimises risks of gene flow and contamination from crops, wild populations of the same species or related species with which it can cross-pollinate, to maintain genetic integrity.**[115]

  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, is recorded, validated and uploaded to the genebank information management system.**

  Data to consider include geographic location and boundaries, slope, climate information, any legal agreements on land tenure, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

[115] See Genebank Standards (Standard 6.1.1): http://www.fao.org/3/a-i3704e.pdf

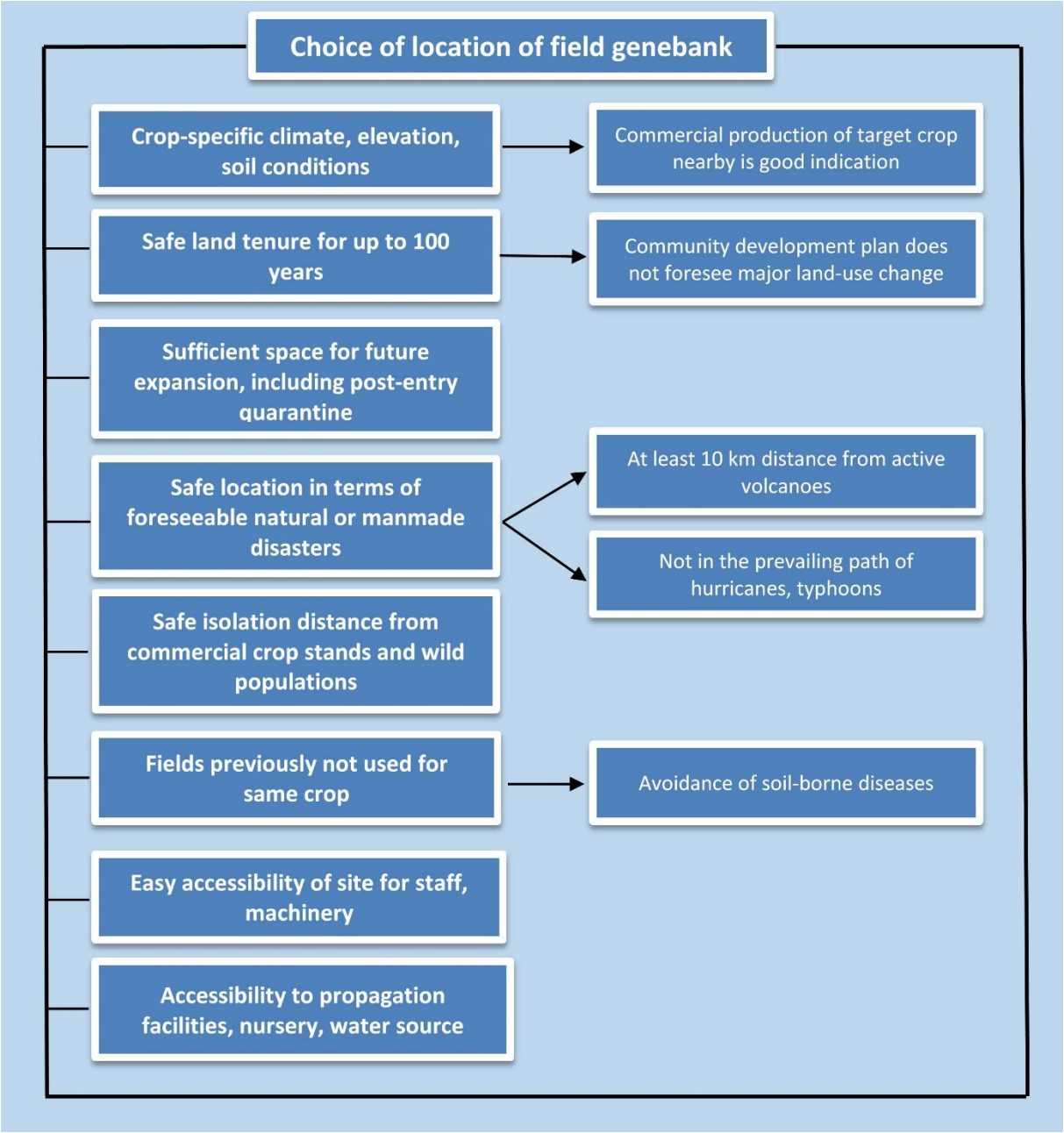

Figure 3. Summary diagram for choice of location of field genebank

3. Acquisition of Germplasm

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

3.1 Germplasm acquired through collecting missions

✓ **A clear strategy for germplasm acquisition is developed according to your institute's mandate.**

Genebank curators may interact with breeders and other scientists before deciding on new acquisitions to ensure that collections remain manageable and meet user's needs.[116] Genebanks may also have a crop or general committee in place. It may be appropriate and useful that:

- the collecting proposal clearly states the purpose of the collecting mission, the target location and methodology;
- a collaboration with an institute or experts from the targeted area be established and guided by regulations for collecting in that area; and
- the mission is planned well in advance to ensure best practices and compliance with regulations and requirements.

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.[117]**

The process of germplasm acquisition is governed by national and international regulations. The genebank should communicate with National Focal Points for the International Treaty for Plant Genetic Resources for Food and Agriculture (Treaty) or the Convention on Biological Diversity (CBD) if other countries are involved in germplasm acquisition. The below information could assist in ensuring compliance with these regulations:

- For collecting missions in your own country, it may be necessary to contact the national competent authority to understand and be compliant 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 or community areas, prior informed consent (PIC) may be required and mutually agreed terms (MAT) [118] 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.**

With the movement of germplasm there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;

[116] Guarino, L.G., Rao, L.R. and Reid, V., 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB international: https://www.bioversityinternational.org/e-library/publications/detail/collecting-plant-genetic-diversity/

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

[118] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf.

  - obtaining an import permit from the relevant authorities in your country;[119]
- passing samples through the relevant quarantine process before being transferred to the genebank;
- 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.[120]**

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

✓ **Propagules are collected from an appropriate number of individual plants, 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 as well as the type and size of the propagule.[121]

✓ **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. Label placement 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.

✓ **The period between collecting, shipping and processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.[122]**

Clonal stocks do not retain viability for a long period of time and vegetative propagules decay easily and quite fast. Transport in tropical countries can be the most challenging, where high temperatures and humidity prevail and where transport may be difficult, slow and uncertain. 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 and transport allows for safe and timely delivery.**

The time needed for document processing, duration of shipment or transit time and conditions (high temperatures and/or humidity in tropical countries) is 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.

[119] 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/

[120] See Genebank Standards (Standard 5.2.3): http://www.fao.org/3/a-i3704e.pdf

[121] The Crop Genebank Knowledge Base provides very useful information on collecting: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

[122] See Genebank Standards (Standard 5.2.4): http://www.fao.org/3/a-i3704e.pdf

- It may be necessary to apply pesticide or fungicide before packaging, but avoid any unnecessary chemical treatment.[123] If applied, declare treatments on each package and in accompanying documentation.
- 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 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 transit of long duration by road, periodic aeration of the collected material may be necessary as a precaution against viability lost.
- Sending shipments the fastest means possible, either by airfreight or courier, and avoid deterioration of seed quality and exposure to adverse environmental conditions.
- Continuous tracking of the package, if possible, will allow for expedient processing at arrival.
- Note: For some crops, such as Musa and cacao, shipment of material through transit or quarantine centres in non-producing countries might be the best solution.

✓ **All incoming material is checked for damage/contamination and processed as to not alter the physiological status in a designated reception area.[124]**

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

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

[124] See Genebank Standards (Standard 5.2.5): http://www.fao.org/3/a-i3704e.pdf

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[125]

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

- Associated data for each sample *obtained* as detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v.2.1) (Box 1);[126]
- Taxonomic identification on species and intraspecific levels if possible, plant population type, habitat and ecology, GPS coordinates, photo images and the substratum in order to provide curators and users of the germplasm with an understanding of its original context;
- Information on origin of the germplasm, traditional knowledge, cultural practices, etc., if collecting from farmers' fields; and
- If a herbarium voucher specimen is obtained as a reference from a population (for example wild species), it is important to use the same collecting number as the collected sample.

Box 1: Minimum passport data
As a minimum, collecting forms should contain:

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

✓ **It is very important to assign a permanent and unique accession number to each seed sample added to the genebank collection.**

Once the curator decides to accept a collected sample in the genebank, a unique accession number must be assigned. A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).

✓ **All acquisition data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

3.2 Germplasm acquired through transfer/donation

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.**[127]

[125] See Genebank Standards (Standard 5.2.2): http://www.fao.org/3/a-i3704e.pdf
[126] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
[127] See Genebank Standards (Standard 5.2.1): http://www.fao.org/3/a-i3704e.pdf

- A Material Transfer Agreement (MTA)[128] or, in case of Annex 1 species under the Treaty,[129] a Standard Material Transfer Agreement (SMTA)[130] may be required and should be signed by the involved parties/proper authorities.
- For donations from institutions, plant breeders, or other germplasm providers without a 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.**

With the movement of germplasm there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;
  - obtaining an import permit from the relevant authorities in your country;[131]
- passing samples through the relevant quarantine process before being transferred to the genebank;
- handling collected 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 and processed as to not alter the physiological status in a designated reception area.[132]**

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

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.[133]**

- It is recommended to request donors that samples be accompanied by the associated data as detailed in the FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1).[134,135]
- The associations of data with the single seed accessions must be clear, e.g. by using accession numbers and/or DOI. Data can be transferred efficiently electronically.

✓ **It is very important to assign a permanent and unique accession number to each seed sample added to the genebank collection.**

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[128] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

[129] http://www.fao.org/3/a-bc084e.pdf

[130] https://mls.planttreaty.org/itt/

[131] 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/

[132] See Genebank Standards (Standard 5.2.5): http://www.fao.org/3/a-i3704e.pdf

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

[134] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

[135] See Box 1

- Once the curator decides to accept a donated sample in the genebank, a unique accession number must be assigned. A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).
    - If the donated material has an accession number, a DOI or both, keep these as alternate identifiers in the passport data. This is a critical measure to ensure the tracking of material and the unambiguous association of information with the material.

✓ **All acquisition data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

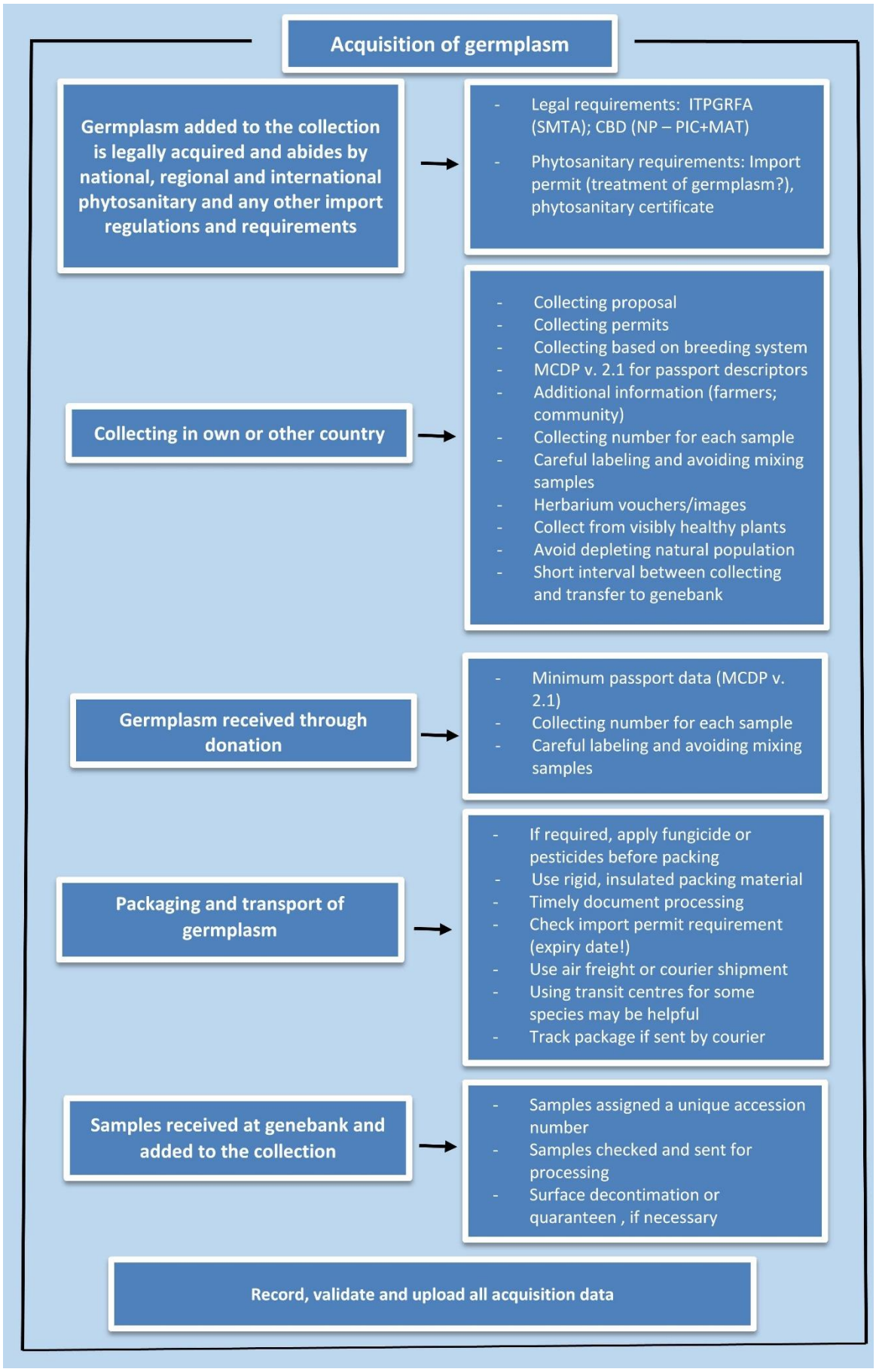

Figure 4. Summary diagram for acquisition of germplasm

4. Establishment of Field Collections

The genebank should have documented policies and/or procedures, as applicable, regarding germplasm in its collections including field preparation, introduction into field and live plant collections, inventory and field maps.

✓ **The field is prepared to further safeguard the collection.**

In addition to choosing a site that minimises risks from natural and manmade disasters,[136] it is important to physically prepare the site to further protect the collection. Some preventative measures include:

- Establishing firebreaks if bushfires are a known risk;
- Installing fencing and hire security guards to avoid vandalism, theft and damage by large animals or humans;
- Installing insect netting and use caging to prevent insect, bird and small mammal damage;
- Inserting hedgerows at the outside of field plots to help prevent pesticide drift and provide security to the accessions from invading animals or unauthorized persons; 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 is undertaken for successful establishment of field collections.**

The land should be prepared that takes into account specific species' needs. Such activities include tilling weeds or herbicide application, deep ploughing, corrective measures for acidic or alkaline soils, etc.

✓ **Field and plot design, individual plot layout, electronic and print maps, as well as barcodes and field labels are incorporated during 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,[137] maintaining both hard and electronic copies (if possible), updating regularly; and
- Ensure that each plot is demarcated with two clearly written water resistant indelible tags or stakes.
- **Note:** Vegetatively propagated annual crops 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 purposes; and
- specific micro-climate requirements such as high or low shade intensity.

[136] See section: Choice of Location of the Field Genebank

[137] See Genebank Standards (Standard 5.3.2): http://www.fao.org/3/a-i3704e.pdf

✓ **Utilize appropriate spacing of plants to allow for proper growth of individual plants.**
It is important to consider the growth habit and the adult size of the plants, the need for irrigation structures, and the ease of maintenance when calculating the size of the plots. It will also be beneficial to establish and follow recommended isolation distances to hinder cross-pollination.

✓ **A sufficient number of individuals are planted in order to capture genetic diversity and ensure safety of each accession.**[138]
To determine the number of individuals to be planted per accession it will be necessary to differentiate between annual and perennial crops and whether the species is propagated by seeds or 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 capture within accession diversity.[139]
- Due to the uniformity of vegetatively propagated species, only a small number of plants is necessary to represent the genetic diversity within the accession and to ensure its security.[140]
- For dioecious species as holly, asparagus, date palm, etc., 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 characterization and evaluation data of the accessions.

✓ **If space allows, reference accessions are planted in the same field to facilitate identification and are established in the field at the correct time of the year, while providing optimum conditions for plant establishment.**
Conditions to consider include temperature, soil moisture levels, soil type, rootstocks, etc. Accessions sensitive to major variations in the environmental conditions may best be grown in greenhouses to protect from heat or cold. For those species requiring shade trees, it is important to choose the shade trees according to the requirement of the species and local conditions.

✓ **Cultural practices provide optimum conditions for plant establishment.**[141]
Appropriate cultivation techniques, specific to the target species, are essential for successful establishment and efficient maintenance of the field genebank and to ensure optimum health and longevity of the plants. Such practices include:
- providing a higher shade intensity and good drainage at the field genebank site to simulate natural growing conditions of crop wild relatives that originated in natural forests;
- practicing weed control for rapid and vigorous plant growth;
- monitoring and treating for pests and diseases;

[138] See Genebank Standards (Standard 5.3.1): http://www.fao.org/3/a-i3704e.pdf
[139] 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/collecting
[140] 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 be in the range from 8 (taro) to 50 plants (shallot, garlic) per accession.
[141] See Genebank Standards (Standard 5.3.3): http://www.fao.org/3/a-i3704e.pdf

- 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, is 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), protocol for breaking dormancy of recalcitrant seed if applicable, method of planting, cultural practices (spacing, weeding, irrigation, fertilizer, pesticide application, etc.) used during establishment and management of the propagated material.

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

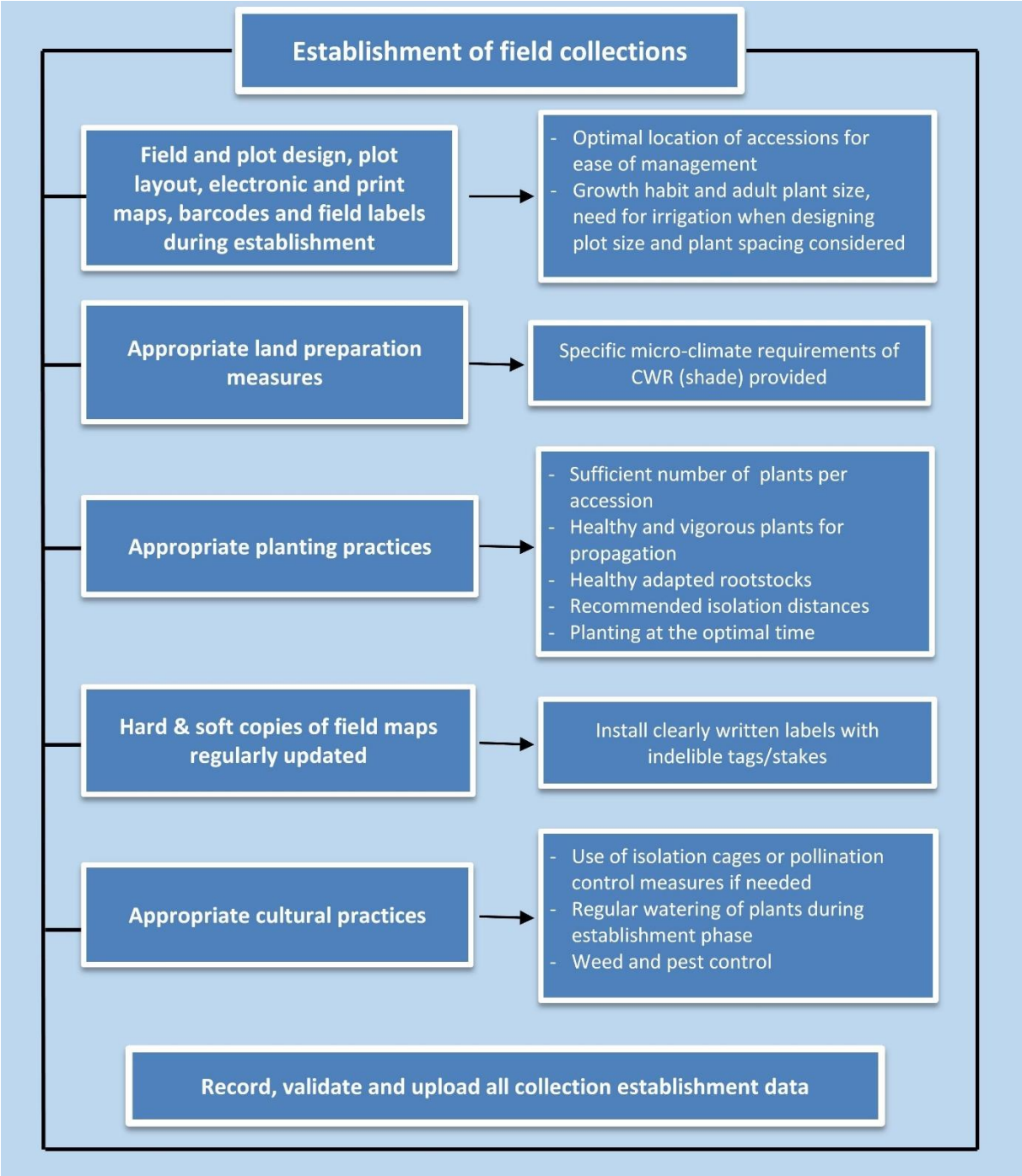

Figure 5. Summary diagram for establishment of field collections

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 the 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.**[142]

Appropriate cultivation practices are essential to ensure optimum plant growth and longevity of the plants. After establishing the collection, it is important to be proactive in supplying 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 that might vary among different groups of accessions;
- practicing weed control as necessary;
- utilising 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 parameters within the plantation and, in 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 (e.g. 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, gene flow from neighbouring plants and inter-growth of accessions.[143] Best practices include:

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

✓ **A system is in place for the routine monitoring for and correct identification of all associated pests and diseases for the range of crops that are included in the collection.**[144]

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, virologists, nematologists, etc., for proper identification and advice on control measures for diseases and pests.

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[142] See Genebank Standards (Standard 5.4.2): http://www.fao.org/3/a-i3704e.pdf
[143] See Genebank Standards (Standard 5.4.3): http://www.fao.org/3/a-i3704e.pdf
[144] 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 both preventative and disease control measures are undertaken such as:

  - 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 breeding grounds for damaging insects, insects transmitting diseases or the build-up of inoculum for next season's crop;
  - periodic screening of material using plant diagnostic kits (ELISA, DNA-based)
  - cleaning any infected clonal materials by thermotherapy and/or tissue culture;
  - keeping insect and pathogen populations under an economic threshold level to avoid major insect and disease infestations; and
  - utilising 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 animal pests and for any possible vandalism.**

- ✓ **All field management data, including associated metadata, is 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, plant removal (dying or dead plants), etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

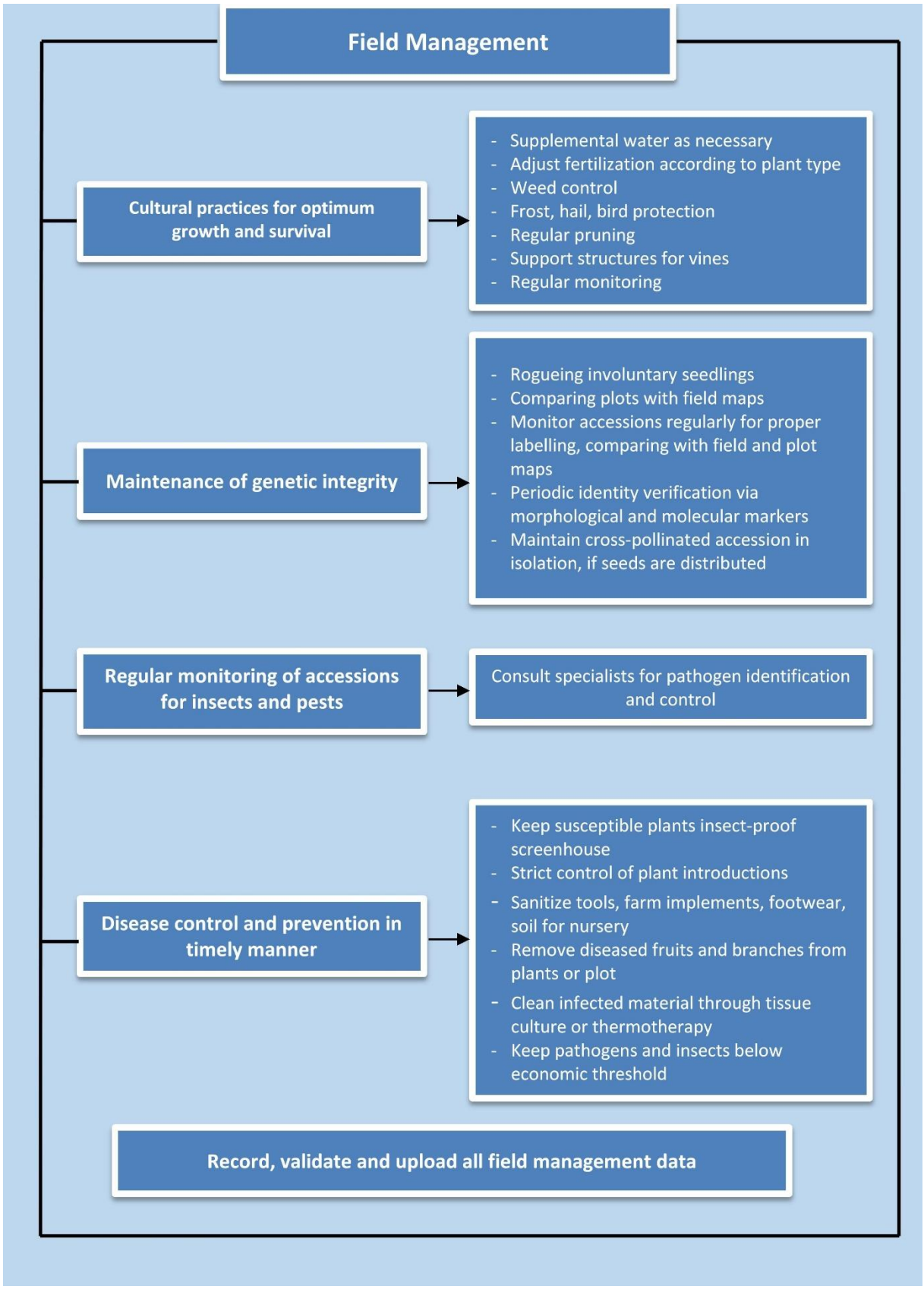

Figure 6. Summary diagram for field management

6. Regeneration and Propagation

The genebank should have a documented policy and/or procedure, as applicable, for regeneration and propagation of germplasm, including step-by-step instructions for the review process, field preparation, selection of accessions, sample size, sowing, crop management, pollination control, identity verification, propagation methodologies and documentation.

✓ **The field collection is regularly monitored to capture any dying or dead plants within an accession.**

A plant may lose vigour or die from different causes due to climatic, edaphic and/or biotic factors. It is important to set viability and quantity thresholds for accessions maintained in the field genebank. [145] Regeneration is carried out for any accessions below these thresholds. For maximum efficiency of a field collection plot, every dead plant should be replaced.[146]

✓ **The timing of regeneration is planned in such a way that it coincides with the normal planting season of the crop.**

Regeneration, like field establishment, will be species and possibly site-specific. It is important to utilise appropriate practices to ensure success, such as:

- planning the raising of rootstocks such 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.
- Note: FAO has published crop calendars for Latin America and Africa which are helpful in this regard.[147]

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

True-to-type plant material should ideally be used for propagation to ensure genetic integrity of the accession.[148] It is not recommended to use seeds for propagation in a field collection unless the population size is represented by a sufficiently large number of plants. Practices to consider include:

- choosing rooting, budding and grafting options for vegetative propagation;[149]
- storing propagation materials in special facilities (e.g., greenhouses, *in vitro*, or freezer) to ensure their health;
- the option of ratooning, i.e. allowing suckers to develop and produce the next crop for collections of edible aroids, which will extend the time between regenerations;[150] 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 root and tuber crops, their propagules must be harvested and replanted each season. Each replanting is considered a regeneration. It is therefore necessary to have designated storage facilities that are, as much as possible, impermeable to insects, rodents and small mammals. The following practices are suggested:

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[145] See section on Establishment of Field Collections for general guidelines.
[146] See Genebank Standards (Standard 5.5.1): http://www.fao.org/3/a-i3704e.pdf
[147] http://www.fao.org/agriculture/seed/cropcalendar/welcome.do)
[148] See Genebank Standards (Standard 5.5.2): http://www.fao.org/3/a-i3704e.pdf
[149] See Roots of Peace (2007) for examples of propagation techniques.
[150] Note: This practice is only recommended when the collection is free from major root and leaf diseases.

- *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 necessary to disinfect the storage propagules after harvest and before storage.
- *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.**

✓ **All field management data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**[151]

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, protocol for breaking dormancy of recalcitrant seed if applicable, management practices employed, method of planting, field conditions, number of plants established for each accession and harvest date, etc.

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

[151] See Genebank Standards (Standard 5.5.3): http://www.fao.org/3/a-i3704e.pdf

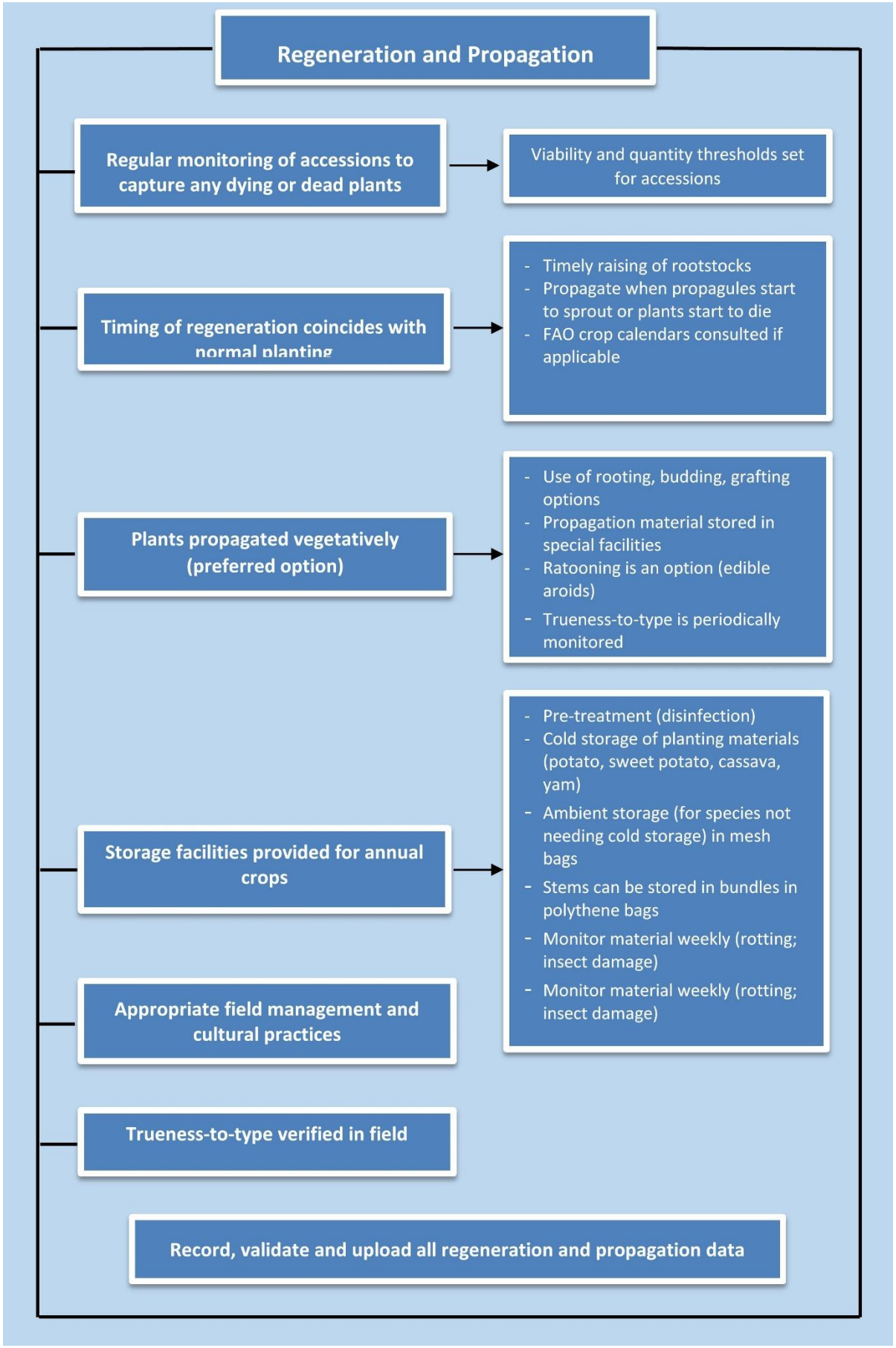

Figure 7. Summary diagram for regeneration and propagation

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 is obtained, descriptors used (taxonomic, morphological, phenotypic, biochemical, nutritional, physiological and molecular), and the manner in which the data is collected and validated.

✓ **Characterization data is obtained for as many accessions as possible and as soon as possible.**
Ideally, all accessions should be characterized.[152] The first opportunity for characterization is during germplasm collection. For all species, it is important that a representative number of plants per accession are characterized.[153] The sooner the information is available, the more likely the accession will be used.

✓ **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 accessions or varieties (controls), as they facilitate the generation of reliable characterization data;[154]
- it is advisable to characterize larger number of accessions at the same time to be efficient;
- creating both hard and soft copies of field maps developed before planting; and
- clearly labelling plots (preferably with bar-codes).

✓ **Germplasm is characterized for a set of highly heritable morphological traits to describe the phenotype of plants, and species-specific characterization procedures are based upon standardized and calibrated measuring formats and categories, following internationally agreed descriptor lists as far as possible.[155]**
The use of standardized crop descriptor lists and calibrated and standardized measuring formats enable the comparison of data across institutions and countries.[156] A wide range of crop descriptor lists has been developed (for example by Bioversity International,[157] The International Union for the Protection of New Varieties of Plants(UPOV),[158] and the National Plant Germplasm System (NPGS) of the United States).[159] If there are no existing descriptor lists for a species, it is recommended to use Bioversity International's Guidelines for Developing Crop Descriptor Lists.[160] It may be helpful to consider:

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[152] See Genebank Standards (Standard 5.6.1): http://www.fao.org/3/a-i3704e.pdf
[153] See Genebank Standards (Standard 5.6.2): http://www.fao.org/3/a-i3704e.pdf
[154] See section 6.4: https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Design_and_analysis_of_evaluation_trials_of_genetic_resources_collections_731.pdf
[155] See Genebank Standards (Standard 5.6.3): http://www.fao.org/3/a-i3704e.pdf
[156] See Genebank Standards (Standard 5.6.4): http://www.fao.org/3/a-i3704e.pdf
[157] https://www.bioversityinternational.org/e-library/publications/descriptors/
[158] https://www.upov.int/test_guidelines/en/
[159] https://www.ars-grin.gov/npgs/cgclist.html
[160] Bioversity International. 2007. Guidelines for the development of crop descriptor lists. Bioversity Technical Bulletin Series, 13. Available at:

- Use of reference accessions in the same field to facilitate scoring;
- utilizing 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 an accession; and
- taking measurements at the plant level rather than at the plot level for species with high levels of variability, to capture the 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.**

Molecular markers help ensure the identity of plants as well as help identify mislabeled plants and duplications.[161] 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 biochemical markers, DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.[162] 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, check accessions or varieties used (for annual species, descriptor measured and results, date recorded, staff responsible, laboratory techniques (molecular, etc.) and dates carried out. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

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.

https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=1053&cHash=39138c10e405dcf0f918c6670c877b4f

[161] See Genebank Standards (Standard 5.6.3): http://www.fao.org/3/a-i3704e.pdf

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

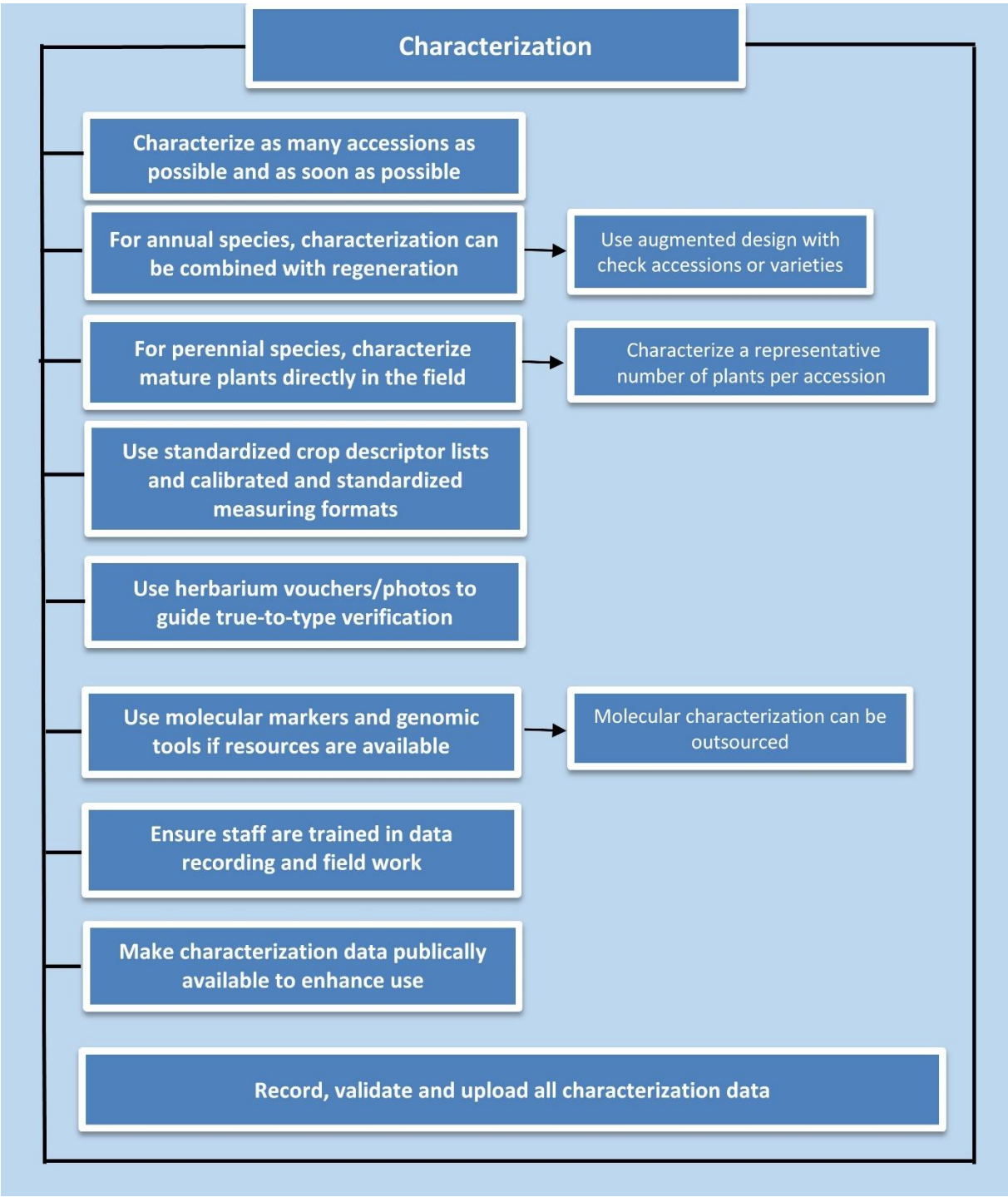

Figure 8. Summary diagram for characterization of germplasm

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 multi-location, 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 is analyzed and validated. The methods/protocols, formats and measurements for evaluation should be properly documented with citations.

✓ **Evaluation data is 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 usually are 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 to request that data be sent back for inclusion in the genebank information management system.

✓ **Experimental designs with replicates are utilized, when feasible, and evaluations conducted in different environments and/or over multiple years.**[163]

Traits measured during evaluation, such as yield and plant height, etc., are mostly quantitative, subject to environmental interaction, and often multigenetically inherited and more difficult to measure. This also applies to agronomic data such as yield or yield components that show strong genotype by environment (G x E) interactions, hence 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, 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 soft copies of field or greenhouse maps developed before planting; and
- clearly labelling plots or greenhouse pots (preferably with bar-codes).

✓ **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 based on measuring.

✓ **All evaluation data, including associated metadata, are recorded, validated and uploaded to the genebank information management system.**[164]

Data to consider include location, planting and harvest dates, cultural practices used (spacing, weeding, irrigation, fertilizer, pesticide application, etc.) and dates, number of replications,

[163] See Genebank Standards (Standard 5.7.3): http://www.fao.org/3/a-i3704e.pdf
[164] See Genebank Standards (Standard 5.7.2): http://www.fao.org/3/a-i3704e.pdf

check accessions or varieties used, descriptor measured, results and date recorded, staff responsible, laboratory techniques used (molecular, etc.) and dates carried out. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

- ✓ **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 its use (see Documentation). The publishing of evaluation data will also promote the use of the germplasm collection, especially by plant breeders.

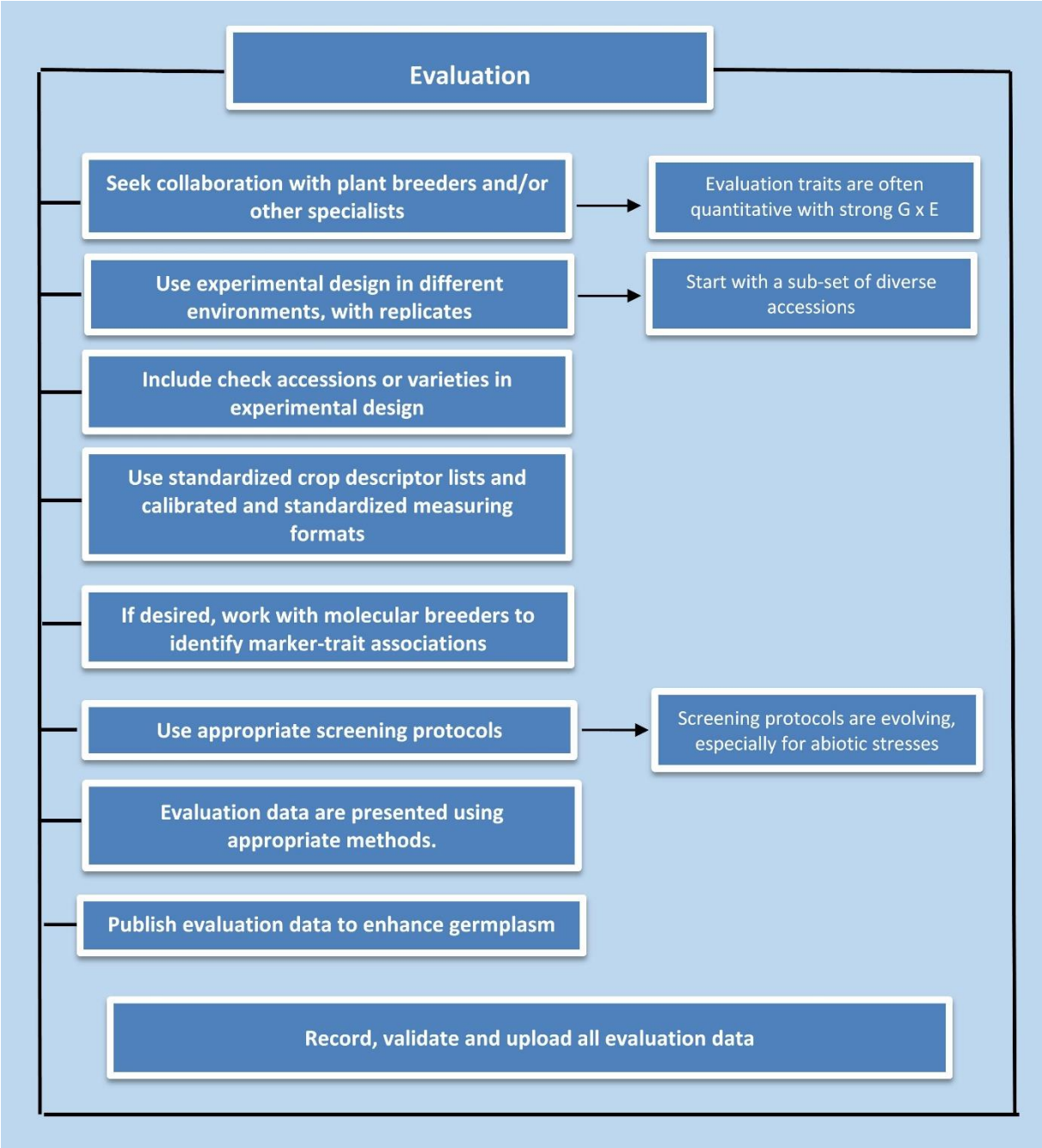

Figure 9. Summary diagram for evaluation of germplasm

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 programs.**

Documentation of passport data of accessions using FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1)[165] and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation[166] facilitates data exchange and comparison across different countries and institutions. Passport data is ideally available for all accessions in the genebank collection.[167] A unique and permanent accession number is a key element of proper documentation and identification and must be assigned to each accession upon accepting it into the genebank collection. In addition, different seed lost or generations of a seed accessions should be identified uniquely. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)[168] is an additional option for information sharing across different information systems and different communities but cannot replace the genebank's accession number.

✓ **A genebank information management system is developed specifically for your genebank or one of the several systems available is used/adapted.**

The genebank information system ideally is designed to manage all data and information generated relating to all aspects of conservation in a field genebank and use of germplasm, including passport, field establishment and management, regeneration, characterization, evaluation and distribution data and metadata.[169] Built-in routines to continuously check inventory and viability and report when regeneration is required should not be missing.

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.[170] Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),[171] the German Genebank Information System (GBIS),[172] Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa)[173] and the SESTO Gene Bank Documentation System of the Nordic Genetic Resource Centre.[174]

✓ **Data are publically available in a search-query database, if possible.**

Publishing data of the genebank holdings increases the opportunities for use of the germplasm conserved 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

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165 https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

166 See Regeneration, Characterization and Evaluation section.

167 See Genebank Standards (Standard 5.8.1): http://www.fao.org/3/a-i3704e.pdf

168 https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

169 See Genebank Standards (Standards 5.8.1 and 5.8.2): http://www.fao.org/3/a-i3704e.pdf

170 https://www.grin-global.org/

171 http://seed.worldveg.org

172 http://www.ipk-gatersleben.de/en/genebank/genebank-documentation/genebank-information-system

173 http://alelo.cenargen.embrapa.br/alelo_en.html

174 https://sesto.nordgen.org/sesto/index.php?thm=sesto

Crop Diversity Trust.[175] It allows sharing accession data from genebanks around the world, and facilitates the ordering of material. Genesys includes accession-level passport, characterization and evaluation data as well as environmental information associated with accession collecting sites. Another option for making publically accessible passport data of genebank accessions is provided by the FAO World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS).[176] By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals,[177] WIEWS stores and publishes accession-level passport data of the largest global inventory of *ex situ* collections.[178]

✓ **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.[179]**

Trained staff responsible for data recording and data entry supports quality control 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. Validation of data by genebank curators and documentation officers before being uploaded into the genebank information management system is recommended.

✓ **Paper data are digitalized and measures in place to monitor hand written and electronic data entries checked for transcription errors.**

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

[175] https://www.genesys-pgr.org/welcome
[176] http://www.fao.org/wiews/en/
[177] https://unstats.un.org/sdgs/metadata?Text=&Goal=2&Target=2.5
[178] http://www.fao.org/wiews/data/ex-situ-sdg-251/overview/en/
[179] See Genebank Standards (Standard 5.8.3): http://www.fao.org/3/a-i3704e.pdf

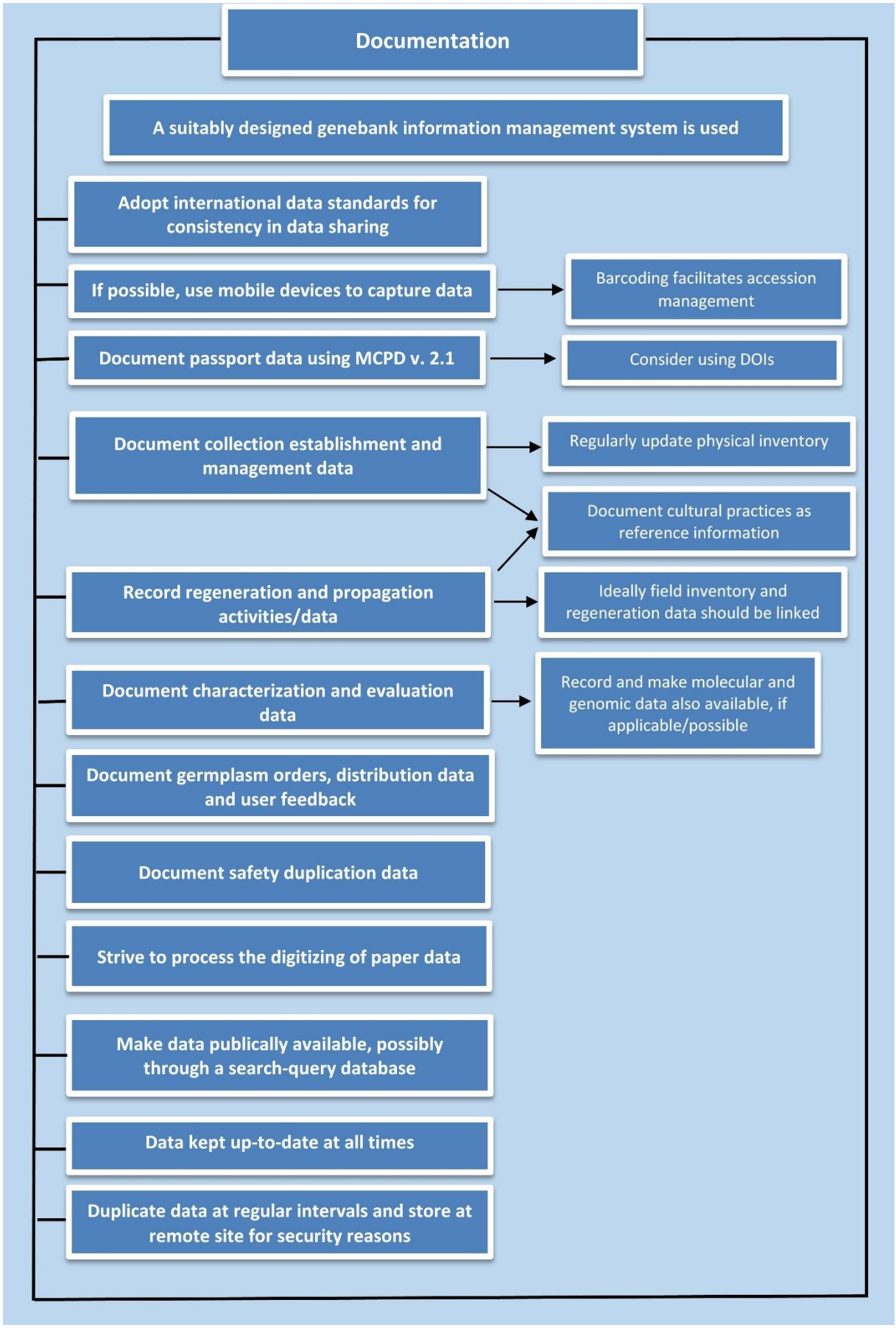

Figure 10. Summary diagram for documentation

10. Distribution and Exchange

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

✓ **The genebank complies with national, regional and international regulations and agreements.[180]**

The process of germplasm distribution is governed by national and international regulations. The below information should assist in ensuring compliance:

- The genebank should communicate with National Focal Points for the Treaty or the CBD if other countries are involved in germplasm distribution.
- If your country is a signatory to the Treaty and you are distributing germplasm of crops or species listed under Annex 1 of the Treaty[181] 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).[182]
- If your 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).[183, 184]

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

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 distributing it to germplasm users.**

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

✓ **The time span 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 in names and numbers, and placement of an outer and inner label for each package ensures that the material is properly identified.

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[180] See Genebank Standards (Standard 5.9.1): http://www.fao.org/3/a-i3704e.pdf

[181] http://www.fao.org/3/a-bc084e.pdf

[182] https://mls.planttreaty.org/itt/; http://www.fao.org/3/be494e/be494e.pdf

[183] An example of a MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively a SMTA can be used or adapted.

[184] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

- ✓ **All required documentation is included inside the shipment (for the recipient) and attached to the outside of the container for the Customs officials to guarantee smooth processing during transit and at the border of the destination country.**[185]

  It is recommended to include all required documentation inside the shipment (for the recipient) and attach to the outside of the container the necessary documentation for the Customs officials to guarantee smooth processing during transit and at the border of the destination country. Documentation to consider includes:[186]

  - a simple packing list with the accession numbers and the number of plantlets/propagating material per accession is sufficient if the genebank information management system allows for on-line access to accession information
  - data on accessions (including an itemized list with accession identification, number of samples, and key passport data);
  - import permit, phytosanitary certificate or customs declaration, if appropriate; and
  - characterization and evaluation data of the accessions, if possible (in the ideal case the accessions number allows retrieving this data from the genebank information management system).

- ✓ **The choice of packaging and transport allows for safe and timely delivery.**

  Ensure that the material reaches the destination genebank in good condition considering 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. Alternatively, if distributing *in vitro* plantlets, use sterile plastic bags.

- ✓ **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, request date, samples requested, samples sent, number of replicates per accession, reference to phytosanitary certificate and SMTA[187] or MTA;[188] shipping log, feedback from user, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

- ✓ **The delivery and condition of the germplasm on arrival at its destination is followed up to confirm that germplasm has reached the recipient in a minimum time.**

  The supplying genebank is recommended to follow up the delivery and condition of the germplasm on arrival at its destination to confirm that germplasm has reached the recipient in a minimum time. It is suggested to track shipment and follow up with the recipient as to the status and performance of the distributed germplasm.

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[185] See Genebank Standards (Standard 5.9.2): http://www.fao.org/3/a-i3704e.pdf
[186] See Genebank Standards (Standard 5.9.3): http://www.fao.org/3/a-i3704e.pdf
[187] https://mls.planttreaty.org/itt/
[188] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

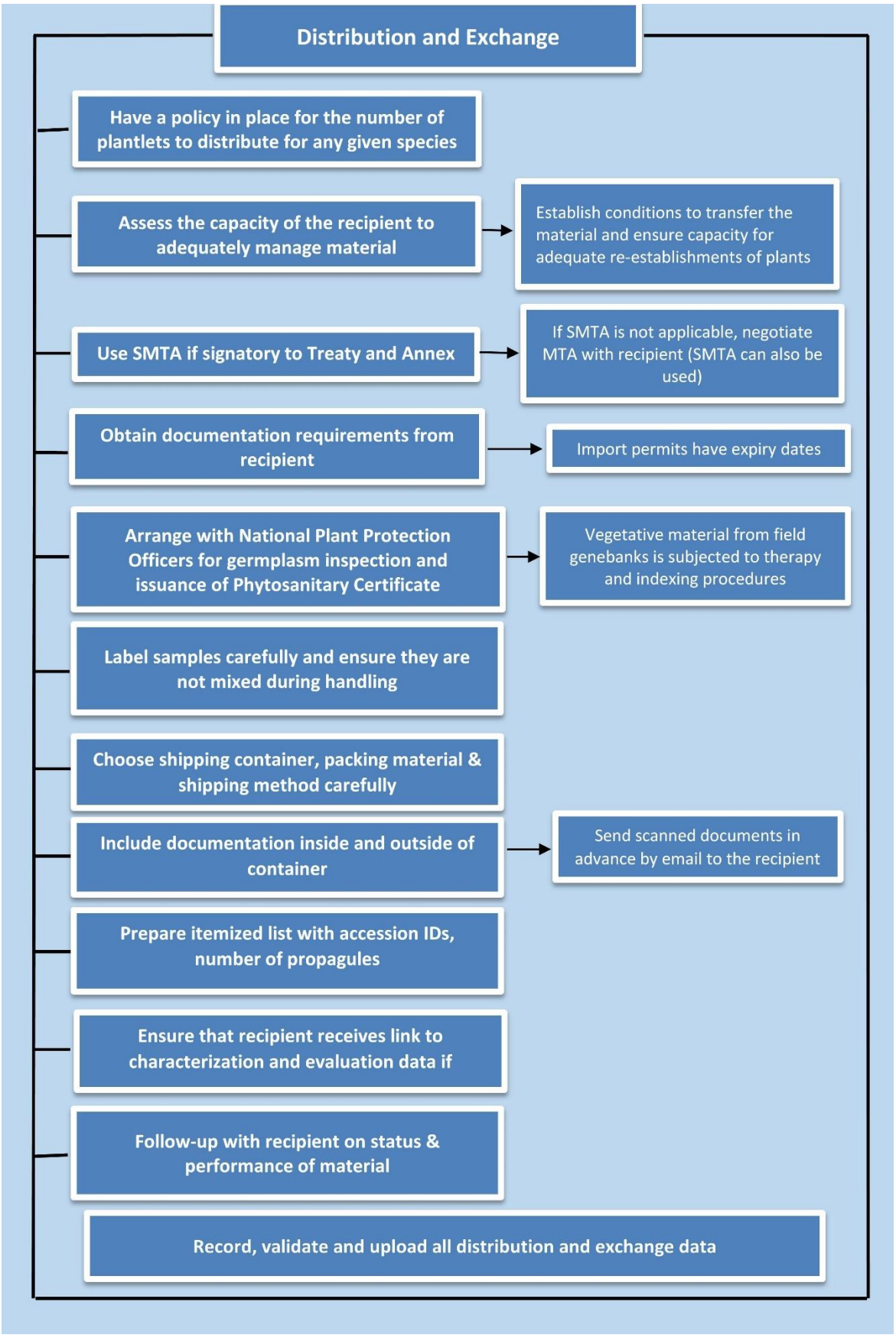

Figure 11. Summary diagram for distribution and exchange of germplasm

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 to check for fulfilment of legal, phytosanitary and other regulations and requirements and step-by step-instructions of consignment preparation, post-consignment follow-up, shipment schedules and monitoring of the viability of safety-duplicated material.[189]

- ✓ **A safety duplicate sample for every original accession is stored in a distant area and/or backed up by an alternative conservation method/strategy.**[190]

  Safety duplicates are deposited at a different location, usually in another country. The location is chosen to minimize possible risks and provides the best possible facilities. Safety duplicates require a location with adequate facilities and staff. The host genebank/institute should have good management capabilities to provide appropriate field and/or *in vitro*[191] conditions for the duplicated accessions. Alternatively, samples can be cryopreserved.[192] The selection of and clear agreement with the chosen holder of the safety duplicate are critical:
  - in a socio-politically and geophysical stable location; and
  - has good management capabilities to provide appropriate conditions for the duplicated accessions and is not constrained by financial and human resources.

- ✓ **A legal agreement setting out the responsibilities of the depositing and the recipient genebank is in place, and the terms and conditions under which material is maintained and managed.**

  If the holding genebank does not already have an agreement with another genebank to duplicate the original accessions, it is recommended to consider 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 with the host genebank early in the planning process on the documentation (genebank and host country) required and an assessment of the customs and quarantine procedures, will be beneficial in ensuring timely dispatch of materials.

- ✓ **The safety duplicate is of high quality and of sufficient quantity.**

  It is the depositor's responsibility to ensure that the deposited material is of high quality. Best practices to consider include:
  - duplicating clean and healthy material; and
  - ensuring that the size of safety-duplicated samples is sufficient to avoid risk of loss.[193]

- ✓ **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 and transport allows for safe and timely delivery.**

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

[190] See Genebank Standards (Standard 5.10.4): http://www.fao.org/3/a-i3704e.pdf

[191] See the Draft Practical Guide for the conservation of PGRFA via *in vitro* culture and Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf

[192] See Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf

[193] 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.

Ensure that the material reaches the destination genebank in good condition considering 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 and distribution is recommended.

- ✓ **Each safety duplicate sample is accompanied by relevant associated information.**

  It is recommended to include minimum information along with the shipment, including an itemized list with accession identification, key passport data, total amount of seeds (by weight or number), type of container, etc. Information may be electronically transferred, as well as printed.

- ✓ **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, number of replicates per accession, packaging information, shipping log, reference to legal agreement, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

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

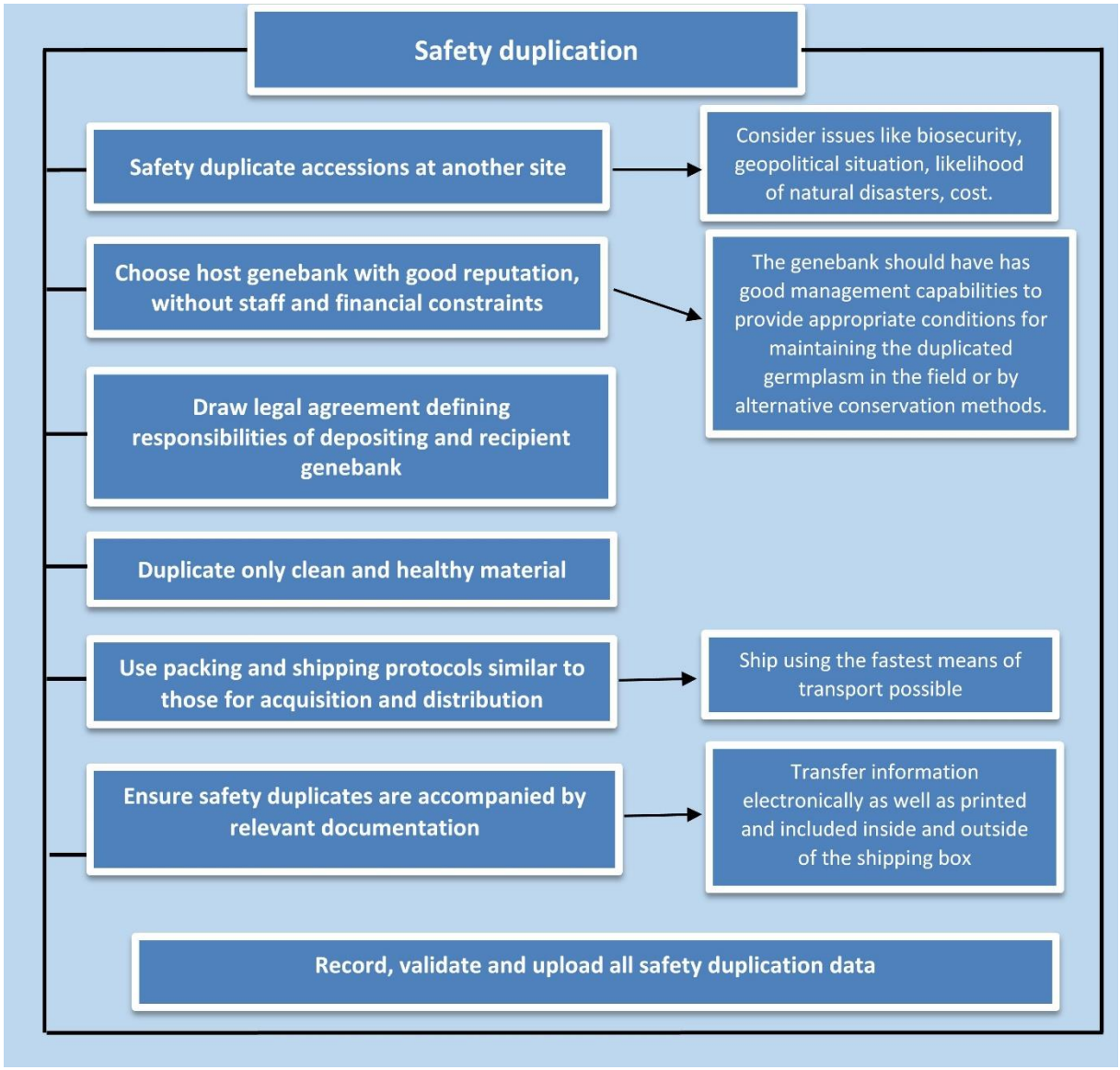

Figure 12. Summary diagram for safety duplication of germplasm

12. Personnel and Security

Personnel

It is recommended that the genebank has a strategy in place for personnel, including a succession plan, and a corresponding budget must be allocated regularly.

✓ **The genebank has a human resource plan with appropriate annual budget allocation and staff have the critical skills, experience and qualifications required to implement all genebank tasks effectively and efficiently.**[194]

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;
- 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 the latest developments;
- rotating tasks to make work as varied as possible and involve all staff (where possible) in meetings and discussions;
- retaining competent staff by providing recognition and rewards for excellent performance;
- crop groups specific curators including technical support staff with knowledge and skills in agriculture, horticulture and taxonomy of cultivated plants and their wild relatives is essential, and
- having access to disciplinary and technical specialists in a range of subject areas, such as physiology, phytopathology, is desirable.

✓ **Risks associated with staffing are included in the risk identification, analysis and management.**

Secure conservation depends on an 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 *inter alia* measures to deal with power cut, fire, flooding, earthquakes, war and civil strife. This strategy and an accompanying action plan is regularly reviewed and updated to take changing circumstances and new technologies into account.

✓ **A risk management strategy is in place.**[195]

A risk management strategy has the following components: [196]

- *Communication and consultation* to 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;

[194] See Genebank Standards (Standard 5.10.1): http://www.fao.org/3/a-i3704e.pdf
[195] See Genebank Standards (Standard 5.10.3): http://www.fao.org/3/a-i3704e.pdf
[196] https://cropgenebank.sgrp.cgiar.org/index.php/management-mainmenu-433/risk-management-mainmenu-236

- *Establishing the context* to consider the objectives/activities/tasks of the genebank, the environment in which the activities operate, and the stakeholders;
- *Risk identification* involves carrying out an inventory of relevant risks to the genebank operations;
- *Risk analysis* involves carrying out an analysis of potential impact (or consequence) of the identified risks and their likelihood (probability);
- *Risk evaluation* to determine the level of risk that is acceptable;
- *Risk treatment* to identify the course of action to deal with those risks where the current total risk rating is considered unacceptable, giving top priority to the highest assessed residual risks; and
- *Monitoring and review* to analyze 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.**

Occupational safety and health (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)[197] provides country profiles on OSH.

✓ **All staff are aware of OSH requirements and are kept up-to-date regarding any changes.**[198]

It is recommended that all genebank staff are 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 lab environments;
- choosing appropriate and nationally approved agrochemicals to reduce risk; and
- providing properly functioning protective equipment and clothing, as required by OSH, and ensuring it is regularly checked and used in the field. The OSH officer is responsible for safety equipment upkeep.

[197] https://www.ilo.org/global/lang--en/index.htm

[198] See Genebank Standards (Standard 5.10.2): http://www.fao.org/3/a-i3704e.pdf

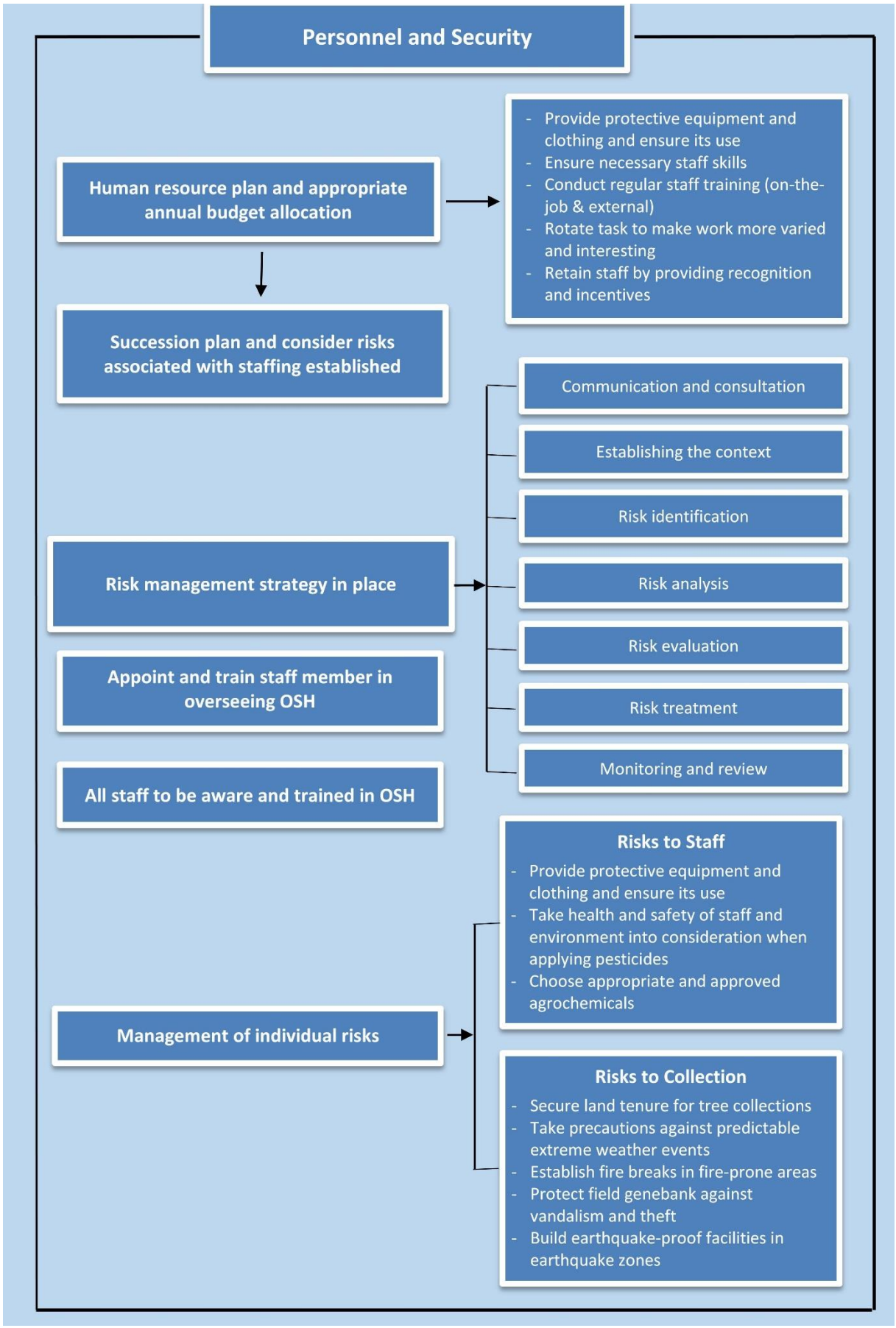

Figure 13. Summary diagram for personnel and security

13. Infrastructure and Equipment

This section considers the suggested infrastructure and equipment for a field genebank (Table 2). The field genebank infrastructure needs 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 is often desirable to keep certain accessions that are difficult to maintain in the field, under more controlled conditions. The screenhouse may also serve for grafting purposes. Shaded nursery facilities are necessary to allow initial growth of grafted or rooted materials until they are ready for field transplanting. Fencing of the field genebank might be necessary to protect the plants from invading animals or theft. The facility should adhere to obligations as required by law and/or other 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 is controlled.

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

Genebank Operation/Management Area
General needs
Office space and supplies; computers, printers and accessories; climate data loggers; mobile devices for electronic data recording and bar code readers; access to scientific and technical literature; Internet access.
Acquisition
Collecting equipment including cloth and/or paper bags, moisture retaining bags/containers, labels (ideally bar-coded), hand lens, scissors, tarpaulins, packaging materials, herbarium presses
Collecting data sheets or mobile devices for electronic data recording, GPS or altimeter, expedition equipment for collecting missions
Incinerator, surface decontamination solutions, knife, forceps, scalpel, balance for weighing fruit and seeds, camera for recording sample on arrival
Field establishment and management
Tractor(s) and attached machinery, equipment for pesticide applications (sprayer, motor-driven or hand-held), irrigation equipment/water supply, grafting and pruning tools, support structures (trees, wooden sticks, wires, etc.), netting, etc.
Regeneration and propagation
Greenhouse or field space for growing cuttings, pots, compost, rootstock, rooting media
Characterization and Evaluation
Access to field, lab or greenhouse areas as required Field/lab/greenhouse equipment and machinery as necessary, according to species and traits being recorded Pot and plot stakes and labels (ideally bar-coded), labelled cloth bags or other appropriate containers Data sheets or mobile devices for electronic data recording, bar code reader

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 viability/health monitoring tools, quantity and distribution tracker is optimal
Distribution and Exchange
Moisture retaining bags/containers for cuttings or sterile plastic bags for *in vitro* germplasm. Heat-sealable plastic bags and sealing machine, labels (preferably barcoded), packaging materials Data sheets or mobile devices for electronic data recording, bar code reader
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 barcoded), packaging materials Data sheets or mobile devices for electronic data recording, bar code reader
Security and Personnel
Generator(s), fire extinction equipment, security cameras, alarm systems, security doors.
Protective clothing

14. Further Information/Reading

The list of references below provide 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*.[199]

General References

Anonymous. Undated. *International Treaty on Plant Genetic Resources for Food and Agriculture | Food and Agriculture Organization of the United Nations*. http://www.fao.org/plant-treaty/en/

Anthony, F., Astorga, C., Avendaño, J. & Dulloo, E. 2007. III. Conservation of coffee genetic resources in the CATIE field genebank. *Complementary strategies for ex situ conservation of coffee (Coffea arabica L.) genetic resources*. In: Engelmann, R., Dulloo, M.E., Astorga, C., Dussert, S. &Anthony, F. (eds.). *Conserving Coffee Genetic Resources*, Bioversity International, Rome

Bramel, P., Krishnan, S., Horna, D., Lainoff, B. & Montagnon, C. 2017. *Global Conservation Strategy for Coffee Genetic Resources*. Crop Trust and World Coffee Research, 72pp. https://worldcoffeeresearch.org/media/documents/Coffee_Strategy_Low_Res.pdf

Bundessortenamt. Undated. Genebank Quality Manual. Federal Plant Variety Office, Hannover, Germany, 33pp. https://www.bundessortenamt.de/bsa/media/Files/PGR_Genebank_Quality_Manual.pdf

Engelmann, F. 2012. Germplasm Collection, Storage and Conservation. In Plant Biotechnology and Agriculture; Altman, A., Hasegawa, P.M., Eds.; Academic Press: Oxford, UK, 2012; pp. 255–268.

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. IPGRI handbooks for genebanks No. 6. Rome, IPGRI. 165 pp. https://www.bioversityinternational.org/e-library/publications/detail/a-guide-to-effective-management-of-germplasm-collections/

FAO. 2014. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rome. http://www.fao.org/3/a-i3704e.pdf

Greene, S.L., Williams, K.A., Khoury, C.K., Kantar, M.B. & Marek, L.F. 2018. *North American Crop Wild Relatives, Volume 1*. Springer Nature Switzerland AG. https://link.springer.com/content/pdf/10.1007%2F978-3-319-95101-0.pdf

Hawkes, J.G., Maxted, N. & Ford-Lloyd, B.V. 2000. Field gene banks, botanic gardens, in vitro, DNA and pollen conservation. In *The Ex Situ Conservation of Plant Genetic Resources* (pp. 92-107). Springer, Dordrecht.

Hawkes, J.G., Maxted, N. & Ford-Lloyd, B.V. 2012. *The Ex Situ Conservation of Plant Genetic Resources*. Springer Science & Business Media, 250pp.

Huaman, Z. (ed.). 1999. *Sweetpotato Germplasm Management (Ipomoea batatas) Training manual*. International Potato Center, Peru. http://cipotato.org/library/pdfdocs/77389.pdf

IPK Gatersleben. undated. *Mansfeld's World Database of Agriculture and Horticultural Crops*. http://mansfeld.ipk-gatersleben.de/apex/f?p=185:3

[199] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf

Maggioni, L., Keller, J. & Astley, D. (eds.) 2001. European Collections of Vegetatively Propagated *Allium*. Report of a Workshop, Gatersleben, Germany, 21-22 May 2001.

Maghradze, D., Maletic, E., Maul, E., Faltus, M. & Failla, O. 2015. Field genebank standards for grapevines (*Vitis vinifera* L.). VITIS-*Journal of Grapevine Research*, *54*:273-279.

Mal, B., Ramamani, Y.S. & Ramanatha Rao, V. (eds.) 2001. *Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia*. Proceedings of the First Annual Meeting of Tropical Fruit Genetic Resources Project, Pattaya, Thailand, 6-9 February 2001. Bioversity International.

Rajasekharan, P.E. & Rao, V.R. 2019. Field genebanks and clonal repositories. In: Rajasekharan, P.E. (ed.) *Conservation and Utilization of Horticultural Genetic Resources* (pp. 507-528). Springer, Singapore.

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

Upadhyaya, H.D. & Gowda, C.L. 2009. *Managing and Enhancing the Use of Germplasm – Strategies and Methodologies*. http://genebank.icrisat.org/PDF/Section/Section4,5.pdf

USDA/ARS. undated. *Taxonomic Information on Cultivated Plants in GRIN-Global*. https://npgsweb.ars-grin.gov/gringlobal/taxon/abouttaxonomy.aspx

Volk, G. M., Namuth-Covert, D. & Byrne, P.F. 2019. Training in plant genetic resources management: A way forward. *Crop Science*, 59(3): 853-857. https://dl.sciencesocieties.org/publications/cs/pdfs/59/3/853

Acquisition and Distribution

Alercia, A., Diulgheroff, S. & Mackay, M. 2015. *FAO/Bioversity Multi-Crop Passport Descriptors V.2.1 [MCPD V.2.1]*. Rome: FAO and Bioversity International, 11 p. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/FAOBIOVERSITY_MULTI-CROP_PASSPORT_DESCRIPTORS_V.2.1_2015_2020.pdf

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

Convention on Biological Diversity. 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

Crop Genebank Knowledge Base. 2018a. Distribution. http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=59&Itemid=208&lang=english

Crop Genebank Knowledge Base. 2018b. Safe transfer of germplasm (STOG). https://cropgenebank.sgrp.cgiar.org/index.php/management-mainmenu-433/stogs-mainmenu-238

Crossa, J. & Vencovsky, R. 2011. Basic sampling strategies: theory and practice. In: Guarino L, Ramanatha Rao V, Goldberg E, editors. 2011. Collecting Plant Genetic Diversity: Technical Guidelines - 2011 Update. Bioversity International, Rome, Italy. ISBN 978- 92-9043- 922- 926. https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

Dansi, A. 2011. Chapter 21. Collecting vegetatively propagated crops (especially roots and tubers). In: Guarino L., Ramanatha Rao V. & Goldberg, E. (eds.) *Collecting Plant Genetic Diversity: Technical*

Guidelines—2011 update. Bioversity International, Rome. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=666

End, M.J., Daymond, A.J. & Hadley, P. 2017. Technical guidelines for the safe movement of cacao germplasm. Revised from the FAO/IPGRI Technical Guidelines No. 20 (Third Update, October 2017). Global Cacao Genetic Resources Network (CacaoNet), Bioversity International.

Eymann, J., Degreef, J., HŠuser, C., Monje, J.C., Samyn, Y. & VandenSpiegel, D., eds. 2010. *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring, Vol. 8.* http://www.abctaxa.be/volumes/volume-8-manual-atbi

Greiber, T., Peña Moreno, S., Ahrén, M., Nieto Carrasco, J., Kamau, E.C., Cabrera Medaglia, J., Oliva, M.J. & Perron-Welch, F. (in cooperation with Ali, N., Williams, C.). 2012. *An Explanatory Guide to the Nagoya Protocol on Access and Benefit-sharing*. IUCN, Gland, Switzerland. xviii + 372 pp. https://cmsdata.iucn.org/downloads/an_explanatory_guide_to_the_nagoya_protocol.pdf

Hay, F.R. & Probert, R.J. 2011. *Collecting and handling seeds in the field*. In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=655

IRRI. undated. *TRANSFER of Plant Genetic Resources for Food and Agriculture*. In: Crop Genebank Knowledge Base. http://www.knowledgebank.irri.org/smta/

Lopez, F. 2015. Digital Object Identifiers (DOIs) in the context of the International Treaty. PowerPoint presentation. http://www.fao.org/fileadmin/templates/agns/WGS/10_FAO_gs_activities_ITPGRFA_20151207.pdf

Mathur, S.B. & Kongsdal, O. 2003. *Common laboratory seed health testing methods for detecting fungi*. Bassersdorf, Switzerland.

Maya-Lastra, C.A. 2016. ColectoR, a digital field notebook for voucher specimen collection for smartphones. *Applications in Plant Sciences*, 4(7). https://doi.org/10.3732/apps.1600035

Moore, G. & Williams, K.A. 2011. *Legal issues in plant germplasm collecting* In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=669

Ni, K.J. 2009. Legal aspects of prior informed consent on access to genetic resources: An analysis of global law-making and local implementation toward an optimal normative construction. *Journal of Transnational Law*, 42, p.227.

Pence, V.C., Sandoval, J., Villalobos, V. & Engelmann, F., eds. 2002. *In vitro* collecting techniques for germplasm conservation. IPGRI Technical Bulletin No 7. Rome. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/technicalbulletin7.pdf

Pence, V.C. & Engelmann, F. 2011. Collecting *in vitro* for genetic resources conservation. In L. Guarino, V.R. Rao & E. Goldberg. Collecting plant genetic diversity: technical guidelines. 2011 update. Rome, Bioversity International. https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

Reid, R. 1995. Collecting tropical forages. In Guarino, L., Ramanantha Rao, V & R. Reid. *Collecting Plant Genetic Diversity-Technical guidelines*, CABI, Wallingford, Oxon, chapter 30. https://cropgenebank.sgrp.cgiar.org/images/file/procedures/collecting1995/Chapter30.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 02. Assessing a population for seed collection.* http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/02-Assessing-population.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 03. Seed collecting techniques*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/03-Collecting-techniques.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 04. Post harvest handling*. http://www.anayglorious.in/sites/default/files/04-Post%20harvest%20handling%20web_0.pdf

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

Veiga, R., Ares, I., Condon, F. & Ferreira, F.R. 2010. Intercambio seguro de recursos fitogenéticos. In Estrategia en los recursos fitogenéticos para los países del Cono Sur/IICA. pp. 75–83. Montevideo: PROCISUR, IICA.

Way, M. 2011. Crop Genebank Knowledge Base. Collecting and recording data in the field: media for data recording. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=659

Establishment of Field Collections and Field Management

Gregory, P.J., Atkinson, C.J., Bengough, A.G., Else, M.A., Fernández-Fernández, F., Harrison, R.J. & Schmidt, S. 2013. Contributions of roots and rootstocks to sustainable intensified crop production. *Journal of Experimental Botany*, 64(5): 1209-1222.

SGRP-CGIAR. Crop Genebank Knowledge Base. Field genebanks. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english

Regeneration and Propagation

Anderson, C.M. 2008. *Recursos genéticos y propagación de variedades comerciales de cítricos.* XII Simposio Internacional de Citricultura. Tamaulipas, México. Available on CD.

Roots of Peace. 2007. Vegetative Propagation Techniques. Perennial Crop Support Series, Jalalabad, Afganistán, Publication No. 2007-003-AFG, USAID, Afganistán. https://www.sas.upenn.edu/~dailey/VegetativePropagationTechniques.pdf

Characterization and Evaluation

Govindaraj, M., Vetriventhan, M. & Srinivasan, M. 2015. Importance of genetic diversity assessment in crop plants and its recent advances: an overview of its analytical perspectives. *Genetics Research International*, Vo. 2015, Article ID 431487, 14 pages. http://dx.doi.org/10.1155/2015/431487

Bioversity International. 2018. Crop descriptors and derived standards. https://www.bioversityinternational.org/fileadmin/user_upload/about_us/news/publications/List_of_Descriptors_Titles_2018.pdf

International Union for the Protection of New Varieties of Plants. 2018. Descriptor lists. http://www.upov.int/test_guidelines/en/list.jsp

USDA/ARS/GRIN. 2018. Crop Descriptor Lists, CGC Membership Rosters, Reports, & Vulnerability Statements. https://www.ars-grin.gov/npgs/cgclist.html#Apple

Molecular Characterization and Evaluation

Arif, I.A., Bakir, M.A., Khan, H.A., Al Farhan, A.H., Al Homaidan, A.A., Bahkali, A.H., Sadoon, M.A. & Shobrak, M. 2010. A Brief Review of Molecular Techniques to Assess Plant Diversity. *International Journal of Molecular Sciences*, 11(5): 2079–2096. https://doi.org/10.3390/ijms11052079

Ayad, W.G., Hodgkin, T., Jaradat, A. & Rao, V.R. 1997. *Molecular genetic techniques for plant genetic resources*. Report on an IPGRI workshop, 9–11 October 1995, Rome, Italy. Rome, Italy, IPGRI, 137 p. http://www.bioversityinternational.org/fileadmin/bioversity/publications/Web_version/675/begin.htm

Bretting, P.K. & Widrlechner, M.P. 1995. Genetic markers and plant genetic resource management. *Plant Breeding Reviews*, 13:11–86.

D'Agostino, N. & Tripodi, P. 2017. NGS-Based Genotyping, High-Throughput Phenotyping and Genome-Wide Association Studies Laid the Foundations for Next-Generation Breeding in Horticultural Crops. *Diversity*, 9(3): 38. https://doi.org/10.3390/d9030038

de Vicente, M.C. & Fulton, T. 2004. *Using molecular marker technology in studies on plant genetic diversity*. Rome, Italy, IPGRI, and Ithaca, New York, USA, Institute for Genetic Diversity. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Molecular_Markers_Volume_1_en.pdf

de Vicente, M.C., Metz, T. & Alercia, A. 2004. *Descriptors for genetic markers technologies*. https://www.bioversityinternational.org/e-library/publications/detail/descriptors-for-genetic-markers-technologies/

Govindaraj, M., Vetriventhan, M. & Srinivasan, M. 2015. Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances: An Overview of Its Analytical Perspectives. In: *Genetics Research International*. https://www.hindawi.com/journals/gri/2015/431487/

Jia, J., Li, H., Zhang, X., Li, Z. & Qiu, L. 2017. Genomics-based plant germplasm research (GPGR). *The Crop Journal*, 5(2): 166–174. https://doi.org/10.1016/j.cj.2016.10.006

Jiang, G.-L. 2013. Molecular Markers and Marker-Assisted Breeding in Plants. In: Andersen, S.B. *Plant Breeding from Laboratories to Fields*. IntechOpen, Denmark. https://doi.org/10.5772/52583

Kaçar, Y.A., Byrne, P.F. & da Silva, J.A.T. 2015 Molecular Markers in Plant Tissue Culture In: da Silva JAT, ed. Floriculture, Ornamental and Plant Biotechnology: Advances and Topical Issues (Vol 11), Edition 1, Chapter 57, pp444-449, Global Science Books.

Karp, A., Kresovich, S., Bhat, K.V., Ayad, W.G. & Hodgkin, T. 1997. *Molecular tools in plant genetic resources conservation: a guide to the technologies*. IPGRI Technical Bulletin No. 2. Rome, IPGRI.

Keilwagen, J., Kilian, B., Özkan, H., Babben, S., Perovic, D., Mayer, K.F.X., Walther, A., Poskar, C.H., Ordon, F., Eversole, K., Börner, A., Ganal, M., Knüpffer, H., Graner, A. & Friedel, S. 2014. Separating the wheat from the chaff – a strategy to utilize plant genetic resources from *ex situ* genebanks. *Scientific Reports*, 4: 5231. https://doi.org/10.1038/srep05231

Kilian, B. & Graner, A. 2012. NGS technologies for analyzing germplasm diversity in genebanks. *Briefings in Functional Genomics*, 11(1): 38–50. https://doi.org/10.1093/bfgp/elr046

Laucou, V., Lacombe, T., Dechesne, F., Siret, R., Bruno, J.P., Dessup, M., Dessup, P., Ortigosa, P., Parra, P., Roux, C., Santoni, S., Varès, D., Perós, J.P., Boursiquot, J.M. & This, P. 2011. High

throughput analysis of grape genetic diversity as a tool for germplasm collection management. *Theoretical and Applied Genetics*, 122(6): 1233–1245.

Mishra, K.K., Fougat, R.S., Ballani, A., Thakur, V., Jha, Y. & Madhumati, B. 2014. Potential and application of molecular markers techniques for plant genome analysis. *International Journal of Pure & Applied Bioscience*, 2(1): 169–188.

van Treuren, R. & van Hintum, T. 2014. Next-generation genebanking: Plant genetic resources management and utilization in the sequencing era. *Plant Genetic Resources*, 12(3): 298–307.

Documentation

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria). 2018. Alelo. http://alelo.cenargen.embrapa.br

GRIN GLOBAL. Undated. Germplasm Resource Information Network Database - Version 1. http://www.grin-global.org/index.php/Main_Page

Ougham, H. & Thomas, I.D. 2014. Germplasm databases and informatics. In: Jackson, M., Ford-Lloyd, B. & Parry, M. *Plant Genetic Resources and Climate Change*, pp.151-165. CAB International, CPI Group, UK.

Turnbull, C.J., Daymond, A.J., Lake, H., Main, B.E., Radha, K., Cryer, N.C., End, M.J. & Hadley, P. 2010. The role of the international cocoa germplasm database and the international cocoa quarantine centre in information management and distribution of cocoa genetic resources. In: 16th International Cocoa Research Conference, November 2009, Bali. http://centaur.reading.ac.uk/28427/

Safety Duplication

Crop Genebank Knowledge Base. Safety duplication. http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=58&Itemid=207&lang=english

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

Bretting, P.K. 2018. 2017 Frank Meyer Medal for Plant Genetic Resources Lecture: Stewards of Our Agricultural Future. Vol. 58 (6): 2233-2240.

Fu, Y.-B. 2017. The vulnerability of plant genetic resources conserved *ex situ*. *Crop Science*, 57(5): 2314. https://doi.org/10.2135/cropsci2017.01.0014

Hummer, K. & Reed, B.M., 1996. Establishment and operation of a temperate clonal field genebank. In *Management of Field and In Vitro Germplasm Collection: Proc. of a Consultation Meeting, CIAT, Cali, Colombia* (pp. 15-20).

Jarret, R.L. & Florkowski, W.J. 1990. *In vitro* active vs. field genebank maintenance of sweet potato germplasm: major costs and considerations. *HortScience*, 25(2): 141-146.

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 during genebank operations to be considered are presented below.

Choice of Location of the Field Genebank

Risk	Risk Control/Mitigation
Loss of adaptive alleles due to selection pressures	Choose site with agro-ecological conditions as similar as possible to the environment where the collected plant materials originated The site is in a location that minimises risks from natural and manmade disasters
Unable to expand or maintain collection over the long-term	Ensure site is secure over the long-term (minimum of 50 years) based on written, guaranteed or gazetted land tenure Ensure that site provides sufficient space for future expansion
Loss if viability/health of collection	Select site suitable for using machinery for mulching, fertilizer and pesticide applications Ensure site has easy access to a water source for pesticide applications and supplemental irrigation as required
Loss of purity due to cross pollination from other accessions of the same species or from nearby crops	Choose site that minimises risks of gene flow and contamination from crops, wild populations of the same species or related species with which it can cross-pollinate

Acquisition

Risk	Risk Control/Mitigation
Diversity of the source population is not adequately represented in the collected sample	Develop and follow agreed collecting plan
Taxonomic misidentification	Include taxonomist in collecting team and hire genebank staff trained in taxonomy Take herbarium vouchers and photos for verification by experts
Mislabeling/loss of labels	Firmly attach one label to collecting bag; include another label inside the collecting bag
Transcription errors	Consider use of mobile devices Data validation
Loss of viability during collecting missions/transport leading to reduced seed longevity (and earlier regeneration)	Timely transfer to controlled conditions Appropriate post-harvest handling according to maturity of seeds and prevailing environmental conditions

Field Management

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

Regeneration and Propagation

Risk	Risk Control/Mitigation
Loss of adaptive alleles due to selection pressures	Follow appropriate cultural practices Regenerate at other sites or outsource if necessary
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. Hand pollinate as required/possible
Misidentification of sample	Check plot and bag labels prior to planting and harvesting; use bar codes
Loss of purity due to due to contamination/mixing of samples during preparation, sowing, harvesting and post-harvest handling	Careful inspection and cleaning of all equipment between each processing step

Characterization

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Appropriate cultural practices Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Use of check accessions/varieties (for annuals) Check plot labels while collecting data Check plot and bag labels prior to sowing and harvesting

Evaluation

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Appropriate statistical design Selection of appropriate locations for planting Appropriate cultural practices Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Use of check accessions/varieties Check plot labels while collecting data Check plot and bag labels prior to sowing and harvesting

Distribution

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Careful packaging Send materials the quickest means possible

Safety duplication

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Careful packaging Send materials the quickest means possible

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

Table of Contents

1. Introduction

Many field and horticultural crops as well as agroforestry species are difficult or impossible to preserve as seeds as they are only producing recalcitrant seeds with a short life span in seed storage, seed production might take many years as is the case for many tree species, or they do not produce seed at all and are vegetatively propagated. *In vitro* conservation offers an option for these species. Further, *in vitro* techniques provide a germplasm storage procedure which combines the possibilities of disease elimination and rapid clonal propagation, 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, both from temperate and tropical origin, including crop plants, for example, potato, yam, cassava, and rare and endangered species. Germplasm can be stored for several months to 2-3 years without subculture, depending on the technique used and on 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.[200]

Conservation in genebanks via *in vitro* culture can be broken down into a process of interrelated operations (Figure 1). This practical guide for the conservation in genebanks via *in vitro* culture suggests practices and activities critical to the underlying genebank principles in 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).[201] The purpose of this guide is to present the information contained in the Genebank Standards in a more user-friendly format detailing the different actions of the genebank workflow in a sequential manner and facilitate more widespread adoption of the Genebank Standards. Genebanks may use the activities outlined in this guide as a basis to develop Standard Operating Procedures (SOPs)[202] and Quality Management Systems[203] for conserving these germplasm collections, defining in detail how to carry out each activity.

This booklet only provides general guidance for the complex steps and decisions required when operating a genebank for *in vitro* culture. Each genebank will have its own circumstances that require careful consideration and, based on experience, procedural adjustments in order to efficiently manage the collections. For detailed technical specifications for the steps outlined in this guide, the genebank staff will need to consult specific sources of information, a few of which are referenced in this booklet.

[200] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf (Chapter 2)
[201] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/3/a-i3704e.pdf
[202] For example, see Standard Operation Procedures (SOP) for IITA *in vitro* genebank: https://www.iita.org/wp-content/uploads/2017/SOP_for_IITA_in_vitro_genebank.pdf
[203] 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

Genebank principle	**Summarized genebank operations**
Identity of accessions	Passport data collected and recorded Botanical identification verified Permanent and unique accession number assigned and used in all documentation Labelling & tracking in genebank Careful processing undertaken
Maintenance of viability	Best practices followed when collecting, processing, introducing into *in vitro* culture and slow-growth storage, regenerating, and transporting *In vitro* culture and slow-growth storage conditions optimized and monitored Regeneration undertaken when necessary
Maintenance of genetic integrity	Collection and maintenance of samples conducted in a manner that ensures they represent original population Best practices followed during packaging, introduction into *in vitro* culture and slow-growth storage and regeneration
Maintenance of germplasm health	Quarantine procedures undertaken when/if needed Best practices followed when collecting, processing, introducing into *in vitro* culture and slow-growth storage, regenerating, and transporting Contamination monitored and managed
Physical security of collections	Risk management strategy developed and implemented Accessions safety duplicated/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, efficient and timely transfer & systems in place to support use of germplasm Relevant documentation provided to recipients of genebank material
Availability of information	Functional genebank information management system in place Passport and accession management data secured by regular data backups Passport and other relevant data available and accessible
Proactive management of genebanks	Standards of Operation developed and available to staff Data and information generated during genebank activities available to managers Well-trained staff employed and protected by Occupational Safety and Health measures Genebank staff capacities kept current and trainings provided as necessary

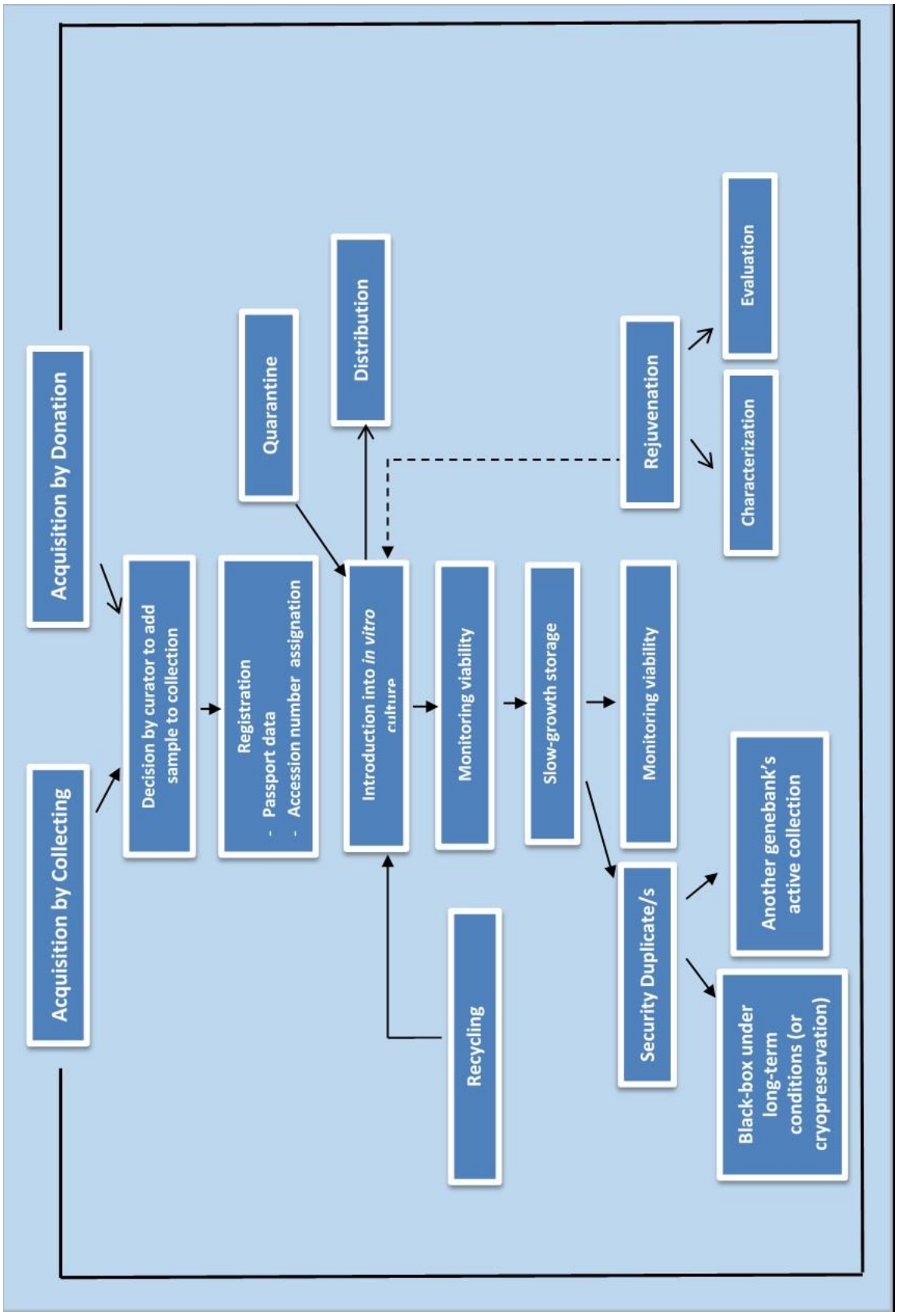

Figure 2. Flow of germplasm in a genebank for *in vitro* conservation. Each step is associated with proper documentation.

2. Acquisition of Germplasm

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

2.1. Germplasm acquired through collecting missions

✓ **A clear strategy for germplasm acquisition is developed according to your institute's mandate.**

Genebank curators may interact with breeders and other scientists before deciding on new acquisitions to ensure that collections remain manageable and meet user's needs.[204] Genebanks may also have a crop or general committee in place. It may be appropriate and useful that:

- the collecting proposal clearly states the purpose of the collecting mission, the target location and methodology;
- a collaboration with an institute or experts from the targeted area be established and guided by regulations for collections in that area; and
- the mission is planned well in advance to ensure best practices and compliance with regulations and requirements.

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.[205]**

The process of germplasm acquisition is governed by national and international regulations. The genebank should communicate with National Focal Points for the International Treaty for Plant Genetic Resources for Food and Agriculture (Treaty) or the Convention on Biological Diversity (CBD) if other countries are involved in germplasm acquisition. The below information could assist in ensuring compliance with these regulations:

- For collecting missions in your own country, it may be necessary to contact the national competent authority to understand and be compliant 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 or community areas, prior informed consent (PIC) may be required and mutually agreed terms (MAT) [206] 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.[207]**

With the movement of germplasm there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;

[204] Guarino, L.G., Rao, L.R. and Reid, V., 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB international: https://www.bioversityinternational.org/e-library/publications/detail/collecting-plant-genetic-diversity/

[205] See Genebank Standards (Standard 6.1.1): http://www.fao.org/3/a-i3704e.pdf

[206] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

[207] See Genebank Standards (Standard 6.1.1): http://www.fao.org/3/a-i3704e.pdf

  - obtaining an import permit from the relevant authorities in your country;[208]
- passing samples through the relevant quarantine process before being transferred to the genebank;
- 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.** [209]

It may be necessary to engage a local expert if the species is not known to you to ensure quality and viability of collected sample, whether vegetative, fruits or recalcitrant seeds. Collecting late-season recalcitrant seeds of any species should be avoided. Whole fruits of consistent 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 are collected from an appropriate number of individual plants[210], 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 as well as the type and size of the propagule.[211]

✓ **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. Label placement 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.

✓ **The period between collecting, shipping and processing and then transferring to the genebank is as short as possible to prevent loss and deterioration of the material.[212]**

The high moisture content of recalcitrant seeds at maturity makes them sensitive to desiccation and chilling injury. Water loss both stimulates germinative metabolism and 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 can be the most challenging, where high temperatures and humidity prevail and where transport may be difficult, slow and uncertain. 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 and transport allows for safe and timely delivery.[213]**

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[208] 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/

[209] See Genebank Standards (Standard 6.1.3): http://www.fao.org/3/a-i3704e.pdf

[210] See Genebank Standards (Standard 6.1.3): http://www.fao.org/3/a-i3704e.pdf

[211] The Crop Genebank Knowledge Base provides very useful information on collecting: https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

[212] See Genebank Standards (Standard 6.1.4): http://www.fao.org/3/a-i3704e.pdf

[213] See Genebank Standards (Standard 6.1.2): http://www.fao.org/3/a-i3704e.pdf

The time needed for document processing, duration of shipment or transit time and conditions (high temperatures and/or humidity in tropical countries) is 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.
    - It may be necessary to apply pesticide or fungicide before packaging, but avoid any unnecessary chemical treatment.[214] 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).
- If available, *in vitro* plantlets are a safe way of moving germplasm. *In vitro* collected samples should be 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 transit of long duration by road, periodic aeration of the collected material may be necessary as a precaution against viability lost.
- Sending shipments the fastest means possible, either by airfreight or courier, should avoid deterioration of seed quality and exposure to adverse environmental conditions.
- Continuous tracking of the package, if possible, will allow for expedient processing at arrival.
- Note: For some crops, such as Musa and cacao, shipment of material through transit or quarantine centres in non-producing countries might be the best solution.

✓ **All incoming material is checked for damage/contamination and processed as to not alter the physiological status in a designated reception area.[215]**

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

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

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

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.**[216]

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

- Associated data for each sample obtained as detailed in the FAO/Bioversity Multi-Crop Passport Descriptors (MCPD v.2.1) (Box 1);[217]
- Taxonomic identification on species and intraspecific levels if possible, plant population type, habitat and ecology, GPS coordinates, photo images and the substratum in order to provide curators and users of the germplasm with an understanding of its original context;
- Information on origin of the germplasm, traditional knowledge, cultural practices, etc., if collecting from farmers' fields; and
- If a herbarium voucher specimen is obtained as a reference from a population (for example wild species), it is important to use the same collecting number as the collected sample.

Box 1: Minimum passport data

As a minimum, collecting forms should contain:

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

✓ **It is very important to assign a permanent and unique accession number to each sample added to the genebank collection.**

Once the curator decides to accept a collected sample in the genebank, a unique accession number must be assigned. A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).

✓ **All acquisition data, including associated metadata, is recorded, validated and uploaded to the genebank information management system.**

The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

2.2 Germplasm acquired through transfer/donation

✓ **Germplasm added to the collection is legally acquired and accompanied by all relevant documentation.**[218]

[216] See Genebank Standards (Standard 6.1.2): http://www.fao.org/3/a-i3704e.pdf

[217] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

[218] See Genebank Standards (Standard 6.1.1): http://www.fao.org/3/a-i3704e.pdf

- A Material Transfer Agreement (MTA)[219] or, in case of Annex 1 species under the Treaty,[220] a Standard Material Transfer Agreement (SMTA)[221] may be required and should be signed by the involved parties/proper authorities.
- For donations from institutions, plant breeders, or other germplasm providers without a 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.**

With the movement of germplasm there is a risk of accidentally introducing plant pests and diseases along with the host plant material. The following steps may assist in the mitigation of such risks, while ensuring compliance with regulations and requirements:

- For materials from another country:
  - obtaining a phytosanitary certificate from the provider country;
  - obtaining an import permit from the relevant authorities in your country;[222]
- passing samples through the relevant quarantine process before being transferred to the genebank;
- handling collected 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 and processed as to not alter the physiological status in a designated reception area.[223]**

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

✓ **Germplasm added to the genebank collection is accompanied by associated data outlined in the FAO/Bioversity Multi-Crop Passport Descriptors.[224]**

- It is recommended to request donors that samples be accompanied by the associated data as detailed in the FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1).[225,226]
- The associations of data with the single seed accessions must be clear, e.g. by using accession numbers and/or DOI. Data can be transferred efficiently electronically.

✓ **It is very important to assign a permanent and unique accession number to each seed sample added to the genebank collection.**

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[219] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

[220] http://www.fao.org/3/a-bc084e.pdf

[221] https://mls.planttreaty.org/itt/

[222] 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/

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

[224] See Genebank Standards (Standard 6.1.2): http://www.fao.org/3/a-i3704e.pdf

[225] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/

[226] See Box 1

- Once the curator decides to accept a donated sample in the genebank, a unique accession number must be assigned. A Digital Object Identifier (DOI) can also be requested from the Secretariat of the Treaty. Both the accession number and the DOI remains with all material derived from the accession during all genebank handling (viability testing, storage, regeneration, and distribution).
- If the donated material has an accession number, a DOI or both, keep these as alternate identifiers in the passport data. This is a critical measure to ensure the tracking of material and the unambiguous association of information with the material.

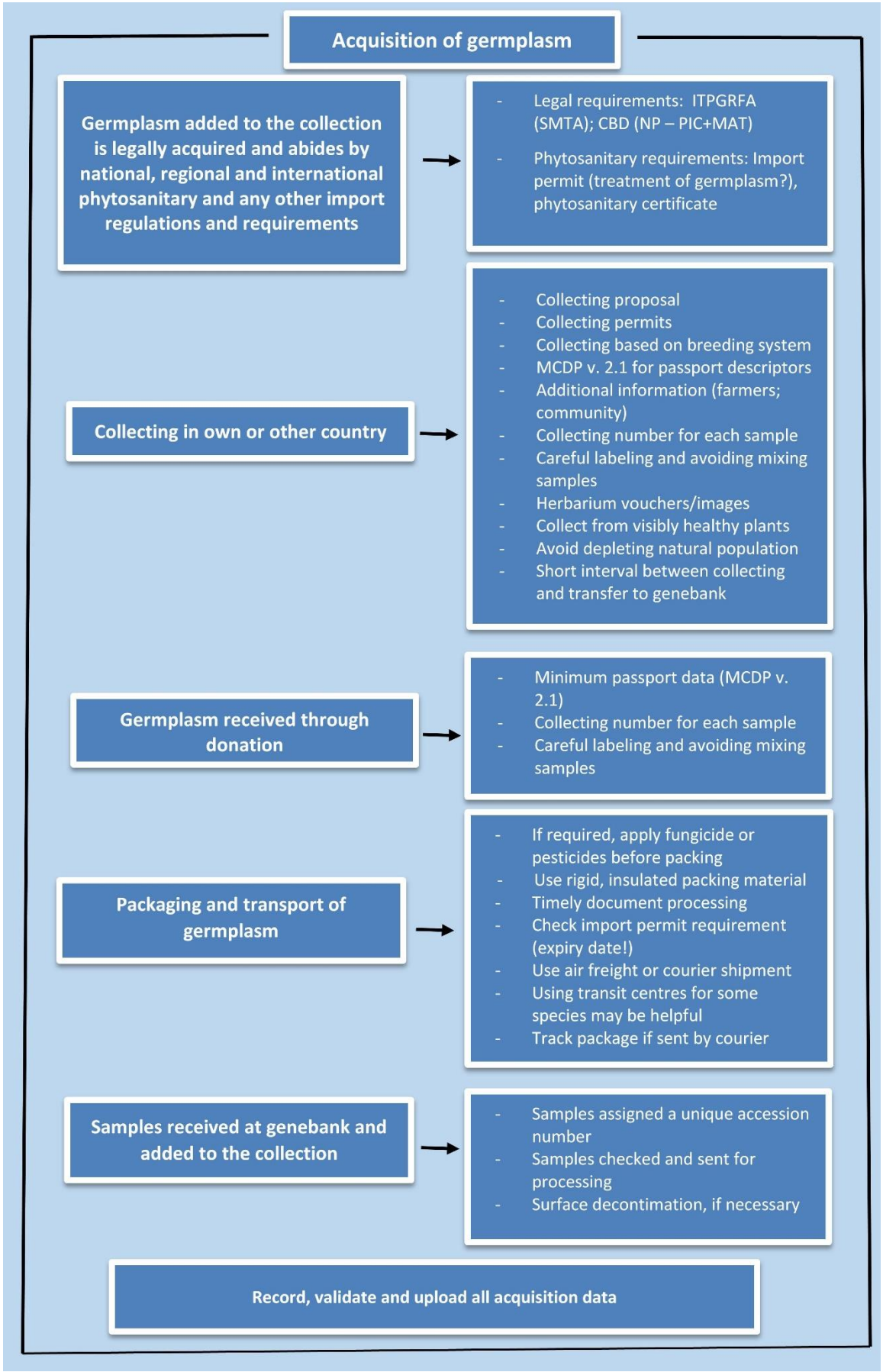

Figure 3. Summary diagram for acquisition of germplasm

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* and propagation/multiplication, medium composition, and light and temperature regimes.

A. *In vitro* culture

✓ **Determine the culture media composition for initiating the explant *in vitro* and for multiplication.**

It may be necessary to carry out a literature review to investigate if 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 other taxa. Excessive use of growth regulators in the multiplication phase of *in vitro* culture should be avoided to minimize the possibility of callus formation in storage later and thus minimize the risk of somaclonal variation.

✓ **The appropriate 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 experiment.**

There are various types of explants frequently used for initiation into culture: nodal segments, apical meristems, roots, cotyledons, embryo, leaf disc, leaf blade, pedicle, petiole, anther, ovary, etc.

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

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

- Explants are obtained from vigorous and healthy mother plants.
- Mother plants are tested for known viruses and determined to be free of viruses.
- Surface decontamination methods are applied that eliminate contaminants from explants excised from field-grown or greenhouse-grown material (*ex vivo*).
- Explants are screened on an appropriate detection medium to ensure it is free from endogenous contamination.[227]

✓ **Once successfully initiated into culture, the accession is multiplied for either normal growth (active growing conditions) or slow growth storage.**

Multiplication is required for rapid propagation of selected materials for research or distribution. Samples under normal *in vitro* growth conditions are usually used to provide the source material for multiplication. It is important to note that the multiplication rate strongly depends on the genomic group to which the accession belongs 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.

✓ **Culture containers are clearly labelled following genebank practice.[228]**

[227] See: Reed, B.M. & Tanprasert, P. 1995. Detection and control of bacterial contaminants of plant tissue cultures. A review of recent literature. Plant Tissue Culture and Biotechnology, 1:137–142. https://www.researchgate.net/publication/222714440_Detection_and_control_of_bacterial_contaminants_of_plant_tissue_cultures_A_review_of_recent_literature

[228] Information on labels could include accession number, date of introduction and line number (number of cuttings from the accession).

B. Slow-growth Storage

✓ **Slow growth storage conditions are optimized for the target species.**[229]

It may be necessary to carry out a literature review to see if 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.[230] Slow growth storage conditions can include:

- Physical growth limitation, including: (a) low temperature; (b) low light/restricted photoperiod; (c) minimal containment; (d) minimal O_2; and (e) osmotic (water) stress.
- Chemical growth limitation, including: (a) growth regulators' retardation and (b) growth inhibitors.
- Nutrient limitation, including: (a) low macro nutrient levels; and (b) low micronutrients levels.
- Avoidance of the formation of callus and other abnormalities, such as hyperhydration.

✓ **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.**

Storage conditions are minimal growth conditions that prove to be acceptable for most genotypes. Not all accessions and genotypes respond equally well to the applied conditions.

✓ **Germplasm for storage are 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 assess the general performance of each culture using the following criteria prior to selection for slow growth storage: vigour, absence of fungal and bacterial contamination, chlorosis, blackening and tissue necrosis.
- Discard contaminated and low quality cultures immediately.
- Propagate cultures onto a new medium if all cultures under evaluation have been assessed below standard because at least one of the 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 such that genetic integrity is maintained[231], 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 than if the accession is in a back-up collection.

✓ **Culture containers are clearly labelled following genebank practice.**[232]

✓ **Any cultures exhibiting somaclonal variation are discarded.**

[229] See Genebank Standards (Standard 6.4.1): http://www.fao.org/3/a-i3704e.pdf
[230] See Further Information/Reading section.
[231] This will vary depending on species.
[232] Information on labels could include accession number, date of introduction and line number (if applicable).

- ✓ **Regular monitoring is carried out to remove those *in vitro* cultures that show any variation from whole plantlets or shoots, contamination, hyperhydration, etc.**

- ✓ **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; duration of subculture period; and any specific growth characteristics, for example, tendency to become hyperhydrated. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

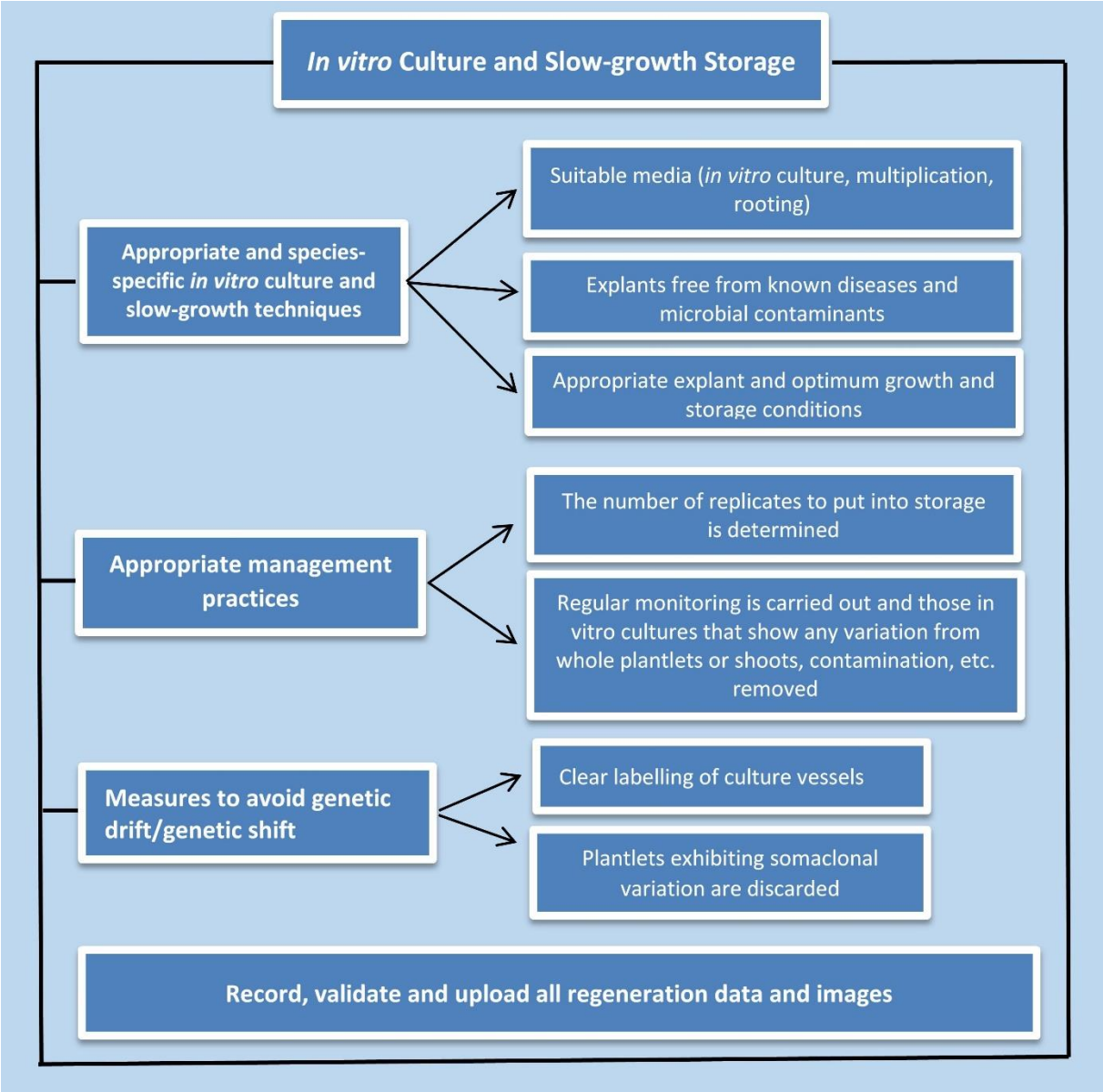

Figure 4. Summary diagram for *in vitro* culture and slow-growth storage of germplasm

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.

Recycling:

- ✓ **Subculturing is carried out at the end of the storage cycle or, when accessions show obvious signs of deterioration and/or when stock becomes low and there is a need for multiplication.**
  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 in 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 via visual assessment and transfer to the field for morphological observations, cytological techniques, or using molecular techniques.**
  It is important to develop a system for monitoring quality, viability, stability and contamination. Quantitative and qualitative criteria should be considered to assess the viability of an accession and identify when it should be subcultured after the material has been maintained for a given time in storage.

Rejuvenation:

- ✓ **Those cultures requiring rejuvenation (transfer of accessions to the greenhouse and field, followed by re-initiation into tissue culture) is determined.**
  Cultures that are too old and have gone through too many cycles of recycling are rejuvenated. 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 are too old.
  - If the number of cultures falls at or above this threshold, the accession should be transferred to the screenhouse or field for rejuvenation and re-initiation into tissue culture.

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

- ✓ **Selected germplasm undergo 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, which includes planting first pots in a greenhouse environment. A number of practices are recommended, including:
  - Selection of plantlets showing a well-developed root and shoot systems for acclimatization;
  - Allowing the media to dry out before acclimatization;
  - Removal of any media from roots before planting in pots; and
  - Use of sterile soil or planting medium.

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

- ✓ **Accessions are verified for their trueness-to-type in the field.**

  Accessions with the same characteristics as the original genotype are considered true-to-type. This is assessed by comparing morphological and taxonomic characteristics of the plants with those of the original accession. Ideally, they 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 which 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 viruses.

- ✓ **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. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

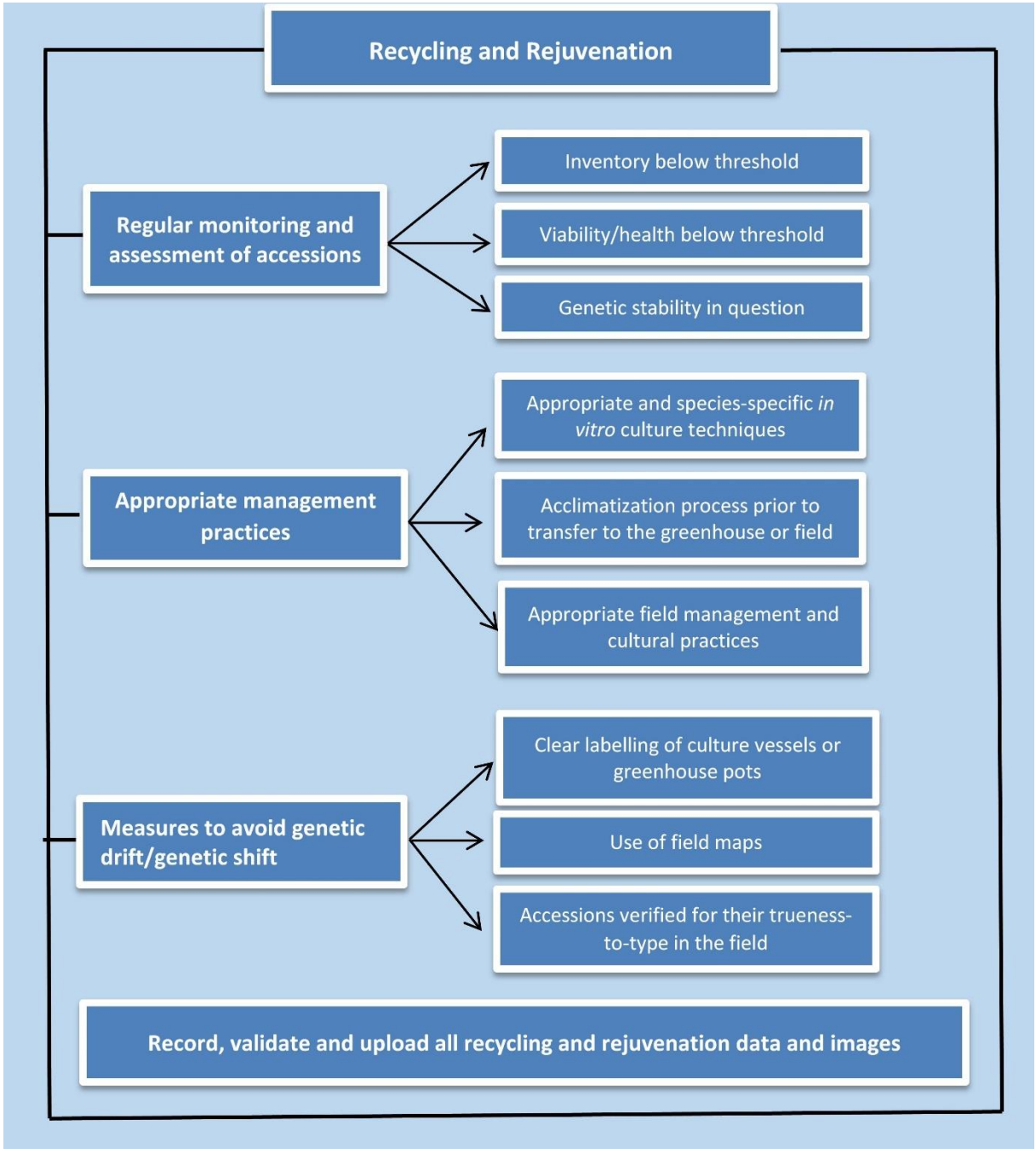

Figure 5. Summary diagram for recycling and rejuvenation of germplasm

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 is collected and validated.

- ✓ **Characterization and evaluation data is obtained for as many accessions as possible and as soon as possible.**

- ✓ **Evaluation is carried out under *in vitro* conditions for certain easily screened traits, for example, for salt and drought tolerance**

- ✓ **Characterization and evaluation of most traits are carried out when accessions are taken out of *in vitro* conditions, except for those traits easily screened under in vitro .**
  Taking accessions out of *in vitro* conditions allows the opportunity for characterization and evaluation data to be generated.

- ✓ **Germplasm is characterized for a set of highly heritable morphological traits to describe the phenotype of plants, and species-specific characterization procedures are based upon standardized and calibrated measuring formats and categories, following internationally agreed descriptor lists as far 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,[233] The International Union for the Protection of New Varieties of Plants(UPOV),[234] and the National Plant Germplasm System (NPGS) of the United States).[235] If there are no existing descriptor lists for a species, it is recommended to use Bioversity International's Guidelines for Developing Crop Descriptor Lists.[236]

- ✓ **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 as well as help identify mislabeled 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 biochemical markers, DNA-based markers and direct sequencing; determining the best method to use will depend on need and resources.[237] Molecular characterization may be outsourced to specialized laboratories.

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[233] https://www.bioversityinternational.org/e-library/publications/descriptors/

[234] https://www.upov.int/test_guidelines/en/

[235] https://www.ars-grin.gov/npgs/cgclist.html

[236] Bioversity International. 2007. Guidelines for the development of crop descriptor lists. Bioversity Technical Bulletin Series, 13. Available at: https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=1053&cHash=39138c10e405dcf0f918c6670c877b4f

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

- ✓ **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. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

- ✓ **Relevant characterization and evaluation 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 and evaluation data is therefore highly recommended.

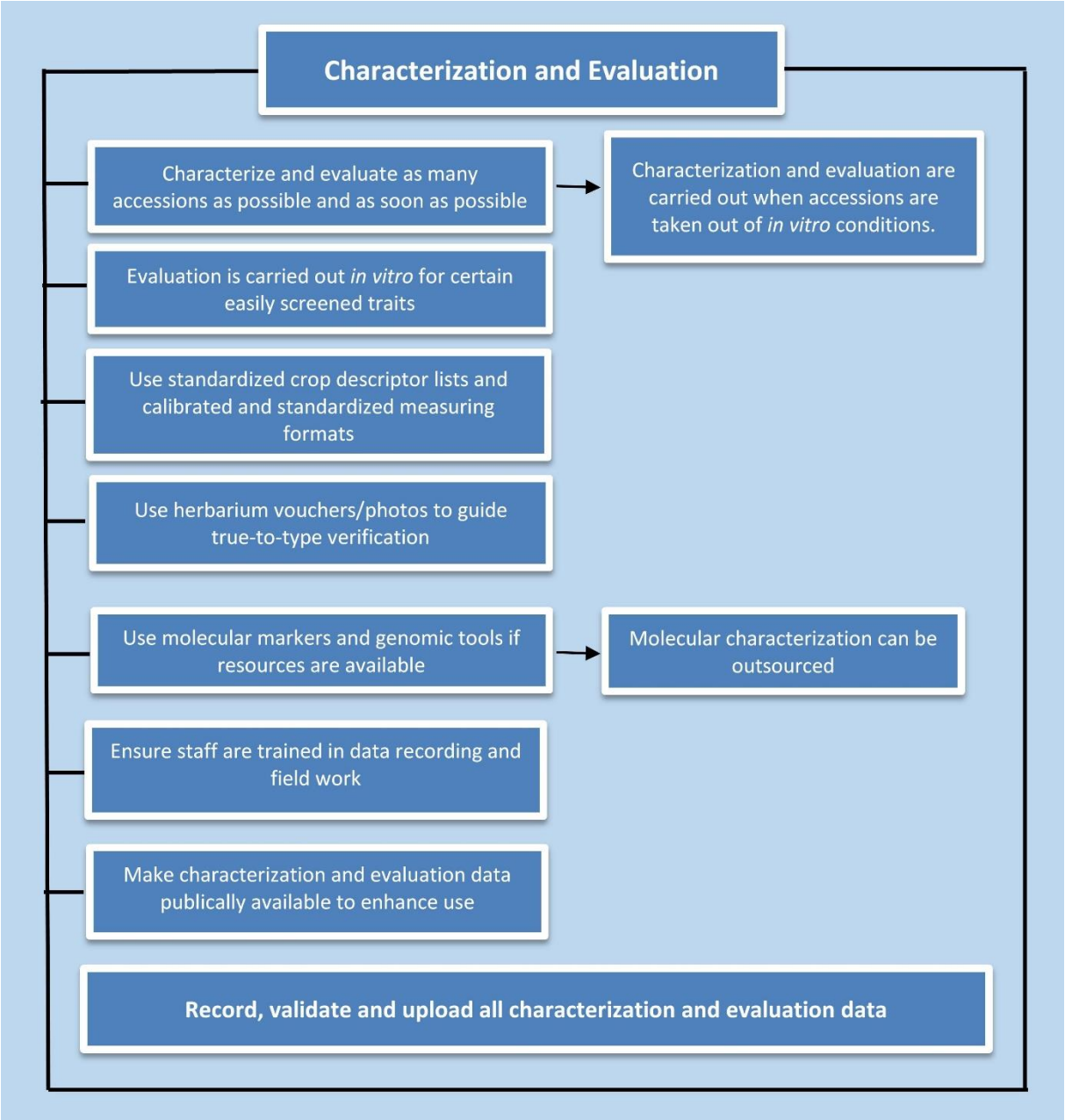

Figure 6. Summary diagram for characterization and evaluation of germplasm

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 programs.**

Documentation of passport data of accessions using FAO/Bioversity multi-crop passport descriptors (MCPD v.2.1)[238] and the use of standardized, internationally agreed, crop-specific descriptors for characterization and evaluation[239] facilitates data exchange and comparison across different countries and institutions. Passport data is ideally available for all accessions in the genebank collection.[240] A unique and permanent accession number is a key element of proper documentation and identification and must be assigned to each accession upon accepting it into the genebank collection. In addition, different seed lost or generations of a seed accessions should be identified uniquely. The voluntary use of Digital Object Identifiers (DOIs; MCPD v.2.1)[241] is an additional option for information sharing across different information systems and different communities but cannot replace the genebank's accession number.

✓ **A genebank information management system is developed specifically for your genebank or one of the several systems available is used/adapted.**

The genebank information system ideally is designed to manage all data and information generated relating to all aspects of *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 routines to continuously check inventory and viability and report when regeneration is required should not be missing.

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.[242] Other systems include the AVRDC Vegetable Genetic Resources Information System (AVGRIS),[243] the German Genebank Information System (GBIS),[244] Alelo developed by the Brazilian Agricultural Research Corporation (Embrapa)[245] and the SESTO Gene Bank Documentation System of the Nordic Genetic Resource Centre.[246]

✓ **Data are publically available in a search-query database, if possible.**

Publishing data of the genebank holdings increases the opportunities for use of the germplasm conserved 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.[247] It allows sharing accession data from genebanks around the world, and

[238] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
[239] See Regeneration, Characterization and Evaluation sections.
[240] See Genebank Standards (Standard 6.6.1): http://www.fao.org/3/a-i3704e.pdf
[241] https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/
[242] https://www.grin-global.org/
[243] http://seed.worldveg.org
[244] http://www.ipk-gatersleben.de/en/genebank/genebank-documentation/genebank-information-system
[245] http://alelo.cenargen.embrapa.br/alelo_en.html
[246] https://sesto.nordgen.org/sesto/index.php?thm=sesto
[247] https://www.genesys-pgr.org/welcome

facilitates the ordering of material. Genesys includes accession-level passport, characterization and evaluation data as well as environmental information associated with accession collecting sites. Another option for making publically accessible passport data of genebank accessions is provided by the FAO World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS).[248] By serving as the data repository for the plant indicator of Target 2.5 of the Sustainable Development Goals,[249] WIEWS stores and publishes accession-level passport data of the largest global inventory of *ex situ* collections.[250]

- ✓ **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.[251]**

  Trained staff responsible for data recording and data entry supports quality control 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. Validation of data by genebank curators and documentation officers before being uploaded into the genebank information management system is recommended.

- ✓ **Paper data are digitalized and measures in place to monitor hand written and electronic data entries checked for transcription errors.**

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

[248] http://www.fao.org/wiews/en/
[249] https://unstats.un.org/sdgs/metadata?Text=&Goal=2&Target=2.5
[250] http://www.fao.org/wiews/data/ex-situ-sdg-251/overview/en/
[251] See Genebank Standards (Standard 6.6.3): http://www.fao.org/3/a-i3704e.pdf

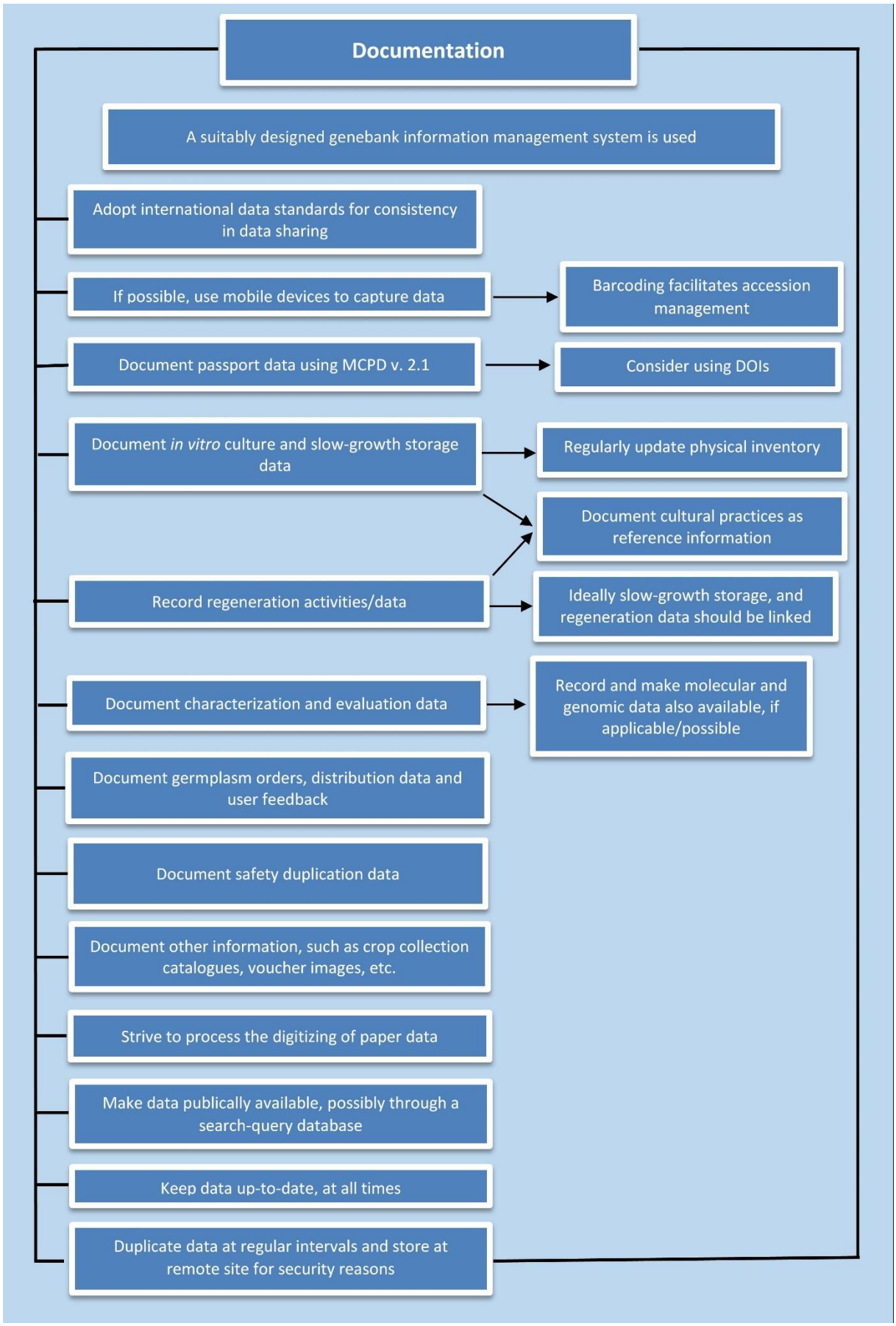

Figure 7. Summary diagram for documentation

7. Distribution and Exchange

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

✓ **The genebank complies with national, regional and international regulations and agreements.**[252]

The process of germplasm distribution is governed by national and international regulations. The below information should assist in ensuring compliance:

- The genebank should communicate with National Focal Points for the Treaty or the CBD if other countries are involved in germplasm distribution.
- If your country is a signatory to the Treaty and you are distributing germplasm of crops or species listed under Annex 1 of the Treaty[253] 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).[254]
- If your 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).[255, 256]

✓ **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.**

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 you need with which to make that assessment.

✓ **Conditions to transfer the material are established between the genebank and recipient and adequate re-establishments of plants from *in vitro* culture is ensured.**[257]

Recipients should have the means to transfer the materials to pots or to the field. Alternatively arrangements should be made to ensure their transfer.

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

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[252] See Genebank Standards (Standard 6.7.1): http://www.fao.org/3/a-i3704e.pdf

[253] http://www.fao.org/3/a-bc084e.pdf

[254] https://mls.planttreaty.org/itt/

[255] An example of a MTA can be found here: https://avrdc.org/?wpfb_dl=524. Alternatively a SMTA can be used or adapted.

[256] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

[257] See Genebank Standards (Standard 6.7.3): http://www.fao.org/3/a-i3704e.pdf

- ✓ **The time span 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 in names and numbers, and placement of an outer and inner label for each package ensures 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 to guarantee smooth processing during transit and at the border of the destination country.**[258]
  It is recommended to include all required documentation inside the shipment (for the recipient) and attach to the outside of the container the necessary documentation for the Customs officials to guarantee smooth processing during transit and at the border of the destination country. Documentation to consider include:
  - a simple packing list with the accession numbers and the number of plantlets per accession is sufficient if the genebank information management system allows for on-line access to accession information
  - data on accessions (including an itemized list with accession identification, seed lot/generation identification, number and/or weights of samples, and key passport data);
  - import permit, phytosanitary certificate, or customs declaration, if appropriate; and
  - characterization and evaluation data of the accessions, if possible (in the ideal case the accessions number allows retrieving this data from the genebank information management system)

- ✓ **The choice of packaging and transport allows for safe and timely delivery.**
  Ensure that the material reaches the destination genebank in good condition considering 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 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..

- ✓ **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, request date, samples requested, samples sent, number of plantlets per sample, reference to phytosanitary certificate and SMTA[259] or MTA;[260] shipping log, feedback from user, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

- ✓ **The delivery and condition of the germplasm on arrival at its destination is followed up to confirm that germplasm has reached the recipient in a minimum time.**
  The supplying genebank is recommended to follow up the delivery and condition of the germplasm on arrival at its destination to confirm that germplasm has reached the recipient in a

[258] See Genebank Standards (Standard 6.7.2): http://www.fao.org/3/a-i3704e.pdf
[259] https://mls.planttreaty.org/itt/
[260] CBD, 2018. Frequently Asked Questions on Access and Benefit-Sharing (ABS). Available at: https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

minimum time. It is suggested to track shipment and follow up with the recipient as to the status and performance of the distributed germplasm.

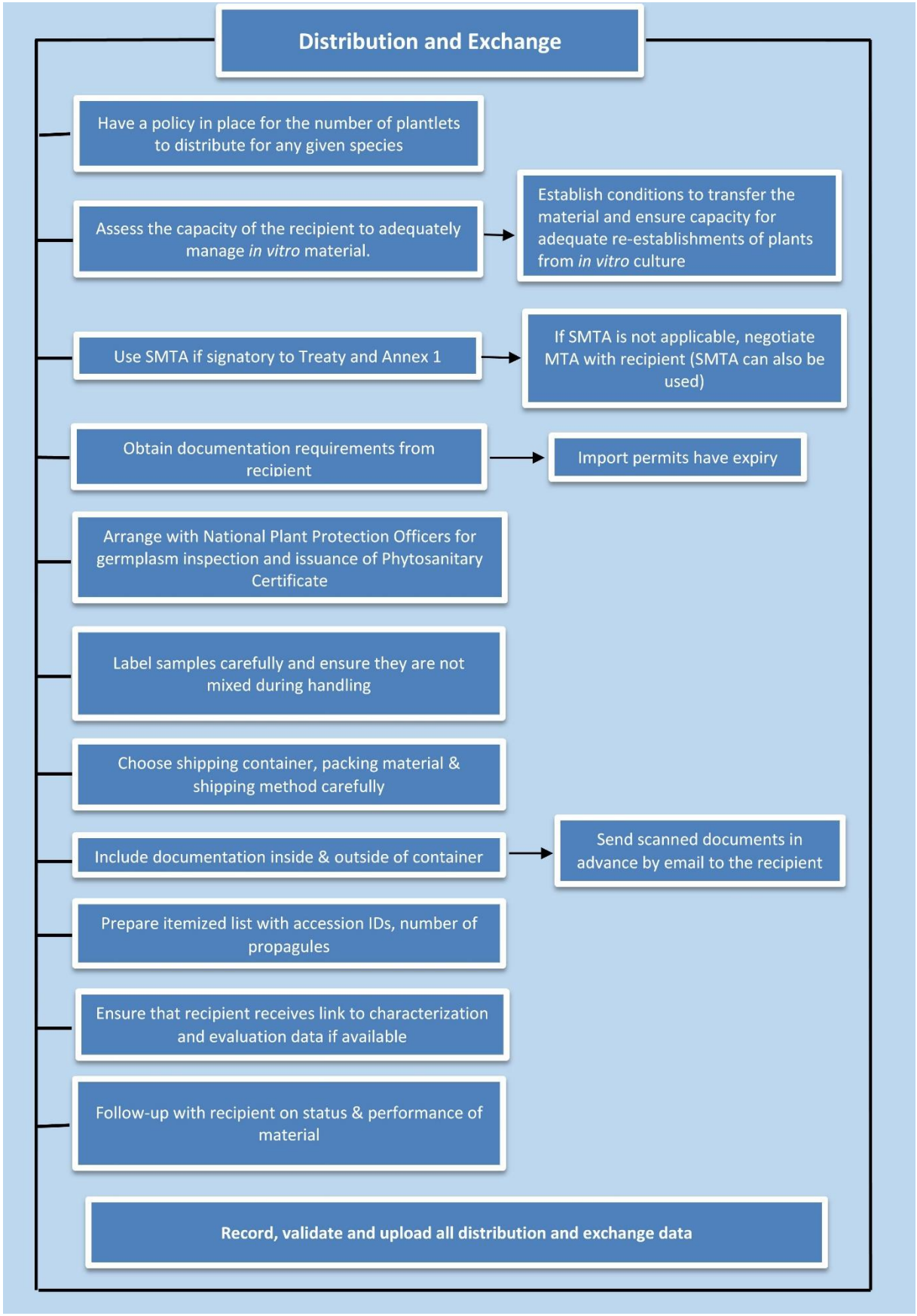

Figure 8. Summary diagram for distribution and exchange of germplasm

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 to check for fulfilment of legal, phytosanitary and other regulations and requirements and step-by step-instructions of consignment preparation, post-consignment follow-up, shipment schedules and monitoring of the viability of safety-duplicated material.

✓ **A safety duplicate sample for every original accession is stored in a distant area, under the same or better conditions than those in the original genebank.**

Safety duplicates are deposited at a different location, usually in another country. The location is chosen to minimize possible risks and provides the best possible facilities.[261] Safety duplicates require a location with adequate facilities and staff. If maintained actively, the host genebank/institute should have good management capabilities to provide appropriate *in vitro* or field conditions for the duplicated accessions. Alternatively, samples may be cryopreserved.[262] The selection of and clear agreement with the chosen holder of the safety duplicate are critical:

- in a socio-politically and geophysical stable location; and
- has good management capabilities to provide appropriate conditions for the duplicated accessions and is not constrained by financial and human resources.

✓ **A legal agreement setting out the responsibilities of the depositing and the recipient genebank is in place, and the terms and conditions under which material is maintained and managed.**

✓ If the holding genebank does not already have an agreement with another genebank to duplicate the original accessions, it is recommended to consider 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 with the host genebank early in the planning process on the documentation (genebank and host country) required and an assessment of the customs and quarantine procedures, will be beneficial in ensuring timely dispatch of materials.

✓ **The safety duplicate is of high quality and of sufficient quantity.**

It is the depositor's responsibility to ensure that the deposited material is of high quality. Best practices to consider include:

- duplicating clean and healthy material; and
- ensuring that the size of safety-duplicated samples is sufficient to avoid risk of loss.[263]

✓ **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 and transport allows for safe and timely delivery.**

Ensure that the material reaches the destination genebank in good condition considering 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.

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[261] See Genebank Standards (Standard 6.8.4): http://www.fao.org/3/a-i3704e.pdf

[262] See Genebank Standards (Chapter 6): http://www.fao.org/3/a-i3704e.pdf

[263] It is recommended to duplicate a minimum of three to five replicates/samples per *in vitro* accession

- ✓ **Each safety duplicate sample is accompanied by relevant associated information.**[264]

  It is recommended to include minimum information along with the shipment, including an itemized list with accession identification, key passport data, total amount of seeds (by weight or number), type of container, etc. Information may be electronically transferred, as well as printed.

- ✓ **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, number of replicates/plantlets per sample, packaging information, shipping log, reference to legal agreement, etc. The use of indelible ink (or pencil) and writing clearly and legibly when recording data is recommended. The use of barcoded labels and barcode readers facilitates accession management and minimizes human error. Consider the use of electronic devices to avoid transcription errors and for ease of uploading.

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

[264] See Genebank Standards (Standard 6.8.5): http://www.fao.org/3/a-i3704e.pdf

Figure 9. Flow diagram for safety duplication of germplasm

9. Personnel and Security

Personnel

It is recommended that the genebank has a strategy in place for personnel, including a succession plan, and a corresponding budget must be allocated regularly.

✓ **The genebank has a human resource plan with appropriate annual budget allocation and staff have the critical skills, experience and qualifications required 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.[265] 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;
- 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 the latest developments;
- rotating tasks to make work as varied as possible and involve all staff (where possible) in meetings and discussions;
- retaining competent staff by providing recognition and rewards for excellent performance;
- crop groups specific curators including technical support staff with knowledge and skills in agriculture, horticulture and taxonomy of cultivated plants and their wild relatives is essential, and
- having access to disciplinary and technical specialists in a range of subject areas, such as physiology, phytopathology, is desirable.

✓ **Risks associated with staffing are included in the risk identification, analysis and management.**

Secure conservation depends on an 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 *inter alia* measures to deal with power cut, fire, flooding, earthquakes, war and civil strife. This strategy and an accompanying action plan is regularly reviewed and updated to take changing circumstances and new technologies into account.[266]

✓ **A risk management strategy is in place.**[267]

A risk management strategy has the following components:

- *Communication and consultation* to 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;

[265] See Genebank Standards (Standard 6.8.3): http://www.fao.org/3/a-i3704e.pdf
[266] See Genebank Standards (Standard 6.8.1): http://www.fao.org/3/a-i3704e.pdf
[267] See Genebank Standards (Standard 6.8.1): http://www.fao.org/3/a-i3704e.pdf

- *Establishing the context* to consider the objectives/activities/tasks of the genebank, the environment in which the activities operate, and the stakeholders;
- *Risk identification* involves carrying out an inventory of relevant risks to the genebank operations;
- *Risk analysis* involves carrying out an analysis of potential impact (or consequence) of the identified risks and their likelihood (probability);
- *Risk evaluation* to determine the level of risk that is acceptable;
- *Risk treatment* to identify the course of action to deal with those risks where the current total risk rating is considered unacceptable, giving top priority to the highest assessed residual risks; and
- *Monitoring and review* to analyze 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.**

Occupational safety and health (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)[268] provides country profiles on OSH.

✓ **All staff are aware of OSH requirements and are kept up-to-date regarding any changes.**[269]

It is recommended that all genebank staff are 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 lab environments;
- choosing appropriate and nationally approved agrochemicals to reduce risk; and
- providing properly functioning protective equipment and clothing, as required by OSH, and ensuring it is regularly checked and used in the field. The OSH officer is responsible for safety equipment upkeep.

[268] https://www.ilo.org/global/lang--en/index.htm

[269] See Genebank Standards (Standard 6.8.2): http://www.fao.org/3/a-i3704e.pdf

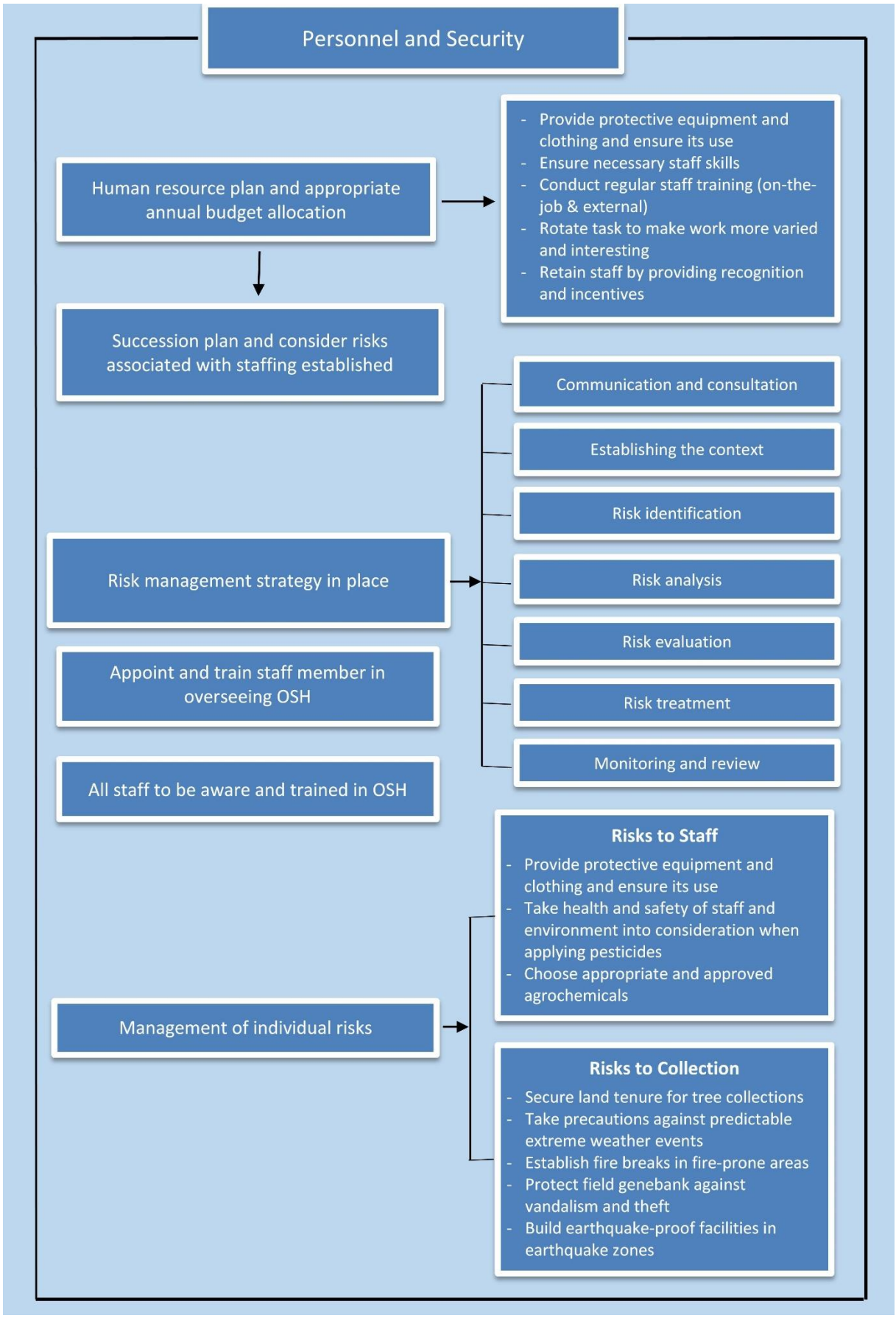

Figure 10. Summary diagram for Personnel and Security

10. Infrastructure and Equipment

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

Table 2. General infrastructure and equipment recommended for an *in vitro* genebank

Genebank Operation/Management Area
General needs
Office space and supplies; computers, printers and accessories; climate data loggers; mobile devices for electronic data recording and bar code readers; access to scientific and technical literature; Internet access.
Acquisition
Collecting equipment including cloth and/or paper bags, moisture retaining bags/containers, labels (ideally bar-coded), hand lens, scissors, tarpaulins, packaging materials, herbarium presses
Collecting data sheets or mobile devices for electronic data recording, GPS or altimeter, expedition equipment for collecting missions
Incinerator, surface decontamination solutions, knife, forceps, scalpel, balance for weighing fruit and seeds, camera for recording sample on arrival
***In vitro* culture and slow growth storage**
Autoclave, pH meter, balance, distilled water apparatus, 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 medium components, temperature controlled growth rooms, growth room shelving and lights, media for screening for contaminants, antibiotics, fungicides
Recycling and Rejuvenation
Greenhouse and/or field environment for growing out *in vitro* plants to assess changes in morphology, pots, compost. Molecular analysis (RAPD, ISSR, SSR) equipment, if possible

Characterization and Evaluation
Access to field, lab or greenhouse areas as required Field/lab/greenhouse equipment and machinery as necessary, according to species and traits being recorded Pot and plot stakes and labels (ideally bar-coded), labelled cloth bags or other appropriate containers Data sheets or mobile devices for electronic data recording, bar code reader
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 viability/health monitoring tools, quantity and distribution tracker is optimal
Distribution and Exchange
Sterile plastic bags for distribution of *in vitro* germplasm. Heat-sealable plastic bags and sealing machine, labels (preferably barcoded), packaging materials Data sheets or mobile devices for electronic data recording, bar code reader
Safety Duplication
Sterile plastic bags for distribution of *in vitro* germplasm. Heat-sealable plastic bags and sealing machine, labels (preferably barcoded), packaging materials Data sheets or mobile devices for electronic data recording, bar code reader
Security and Personnel
Generator(s), fire extinction equipment, security cameras, alarm systems, security doors.
Protective clothing

11. Further Information/Reading

General References

Anonymous. undated. *International Treaty on Plant Genetic Resources for Food and Agriculture | Food and Agriculture Organization of the United Nations*. http://www.fao.org/plant-treaty/en/

Ebert, A.W. & Waqainabete, L.M. 2018. Conserving and sharing taro genetic resources for the benefit of global taro cultivation: a core contribution of the centre for Pacific crops and trees. *Biopreservation and Biobanking*, 16(5): 361-367**.** https://www.liebertpub.com/doi/full/10.1089/bio.2018.0017

Engelmann, F. 2012. Germplasm Collection, Storage and Conservation. In Plant Biotechnology and Agriculture; Altman, A., Hasegawa, P.M., Eds.; Academic Press: Oxford, UK, 2012; pp. 255–268.

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. IPGRI handbooks for genebanks No. 6. Rome, IPGRI. 165 pp. https://www.bioversityinternational.org/e-library/publications/detail/a-guide-to-effective-management-of-germplasm-collections/

FAO. 2014. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rome. http://www.fao.org/3/a-i3704e.pdf

Greene, S.L., Williams, K.A., Khoury, C.K., Kantar, M.B. & Marek, L.F. 2018. *North American Crop Wild Relatives, Volume 1*. Springer Nature Switzerland AG. https://link.springer.com/content/pdf/10.1007%2F978-3-319-95101-0.pdf

Gueye, B., Adeyemi, A., Debiru, M., Akinyemi, B., Olagunju, M., Okeowo, A., Otupa, S. & Dumet, D. 2012. Standard Operation Procedures (SOP) for IITA *in vitro* genebank. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. https://www.iita.org/wp-content/uploads/2017/SOP_for_IITA_in_vitro_genebank.pdf

IPK Gatersleben. undated. *Mansfeld's World Database of Agriculture and Horticultural Crops*. http://mansfeld.ipk-gatersleben.de/apex/f?p=185:3

Normah, M.N., Kean, C.W., Vun, Y.L. & Mohamed-Hussein, Z.A. 2011. *In vitro* conservation of Malaysian biodiversity – achievements, challenges and future directions. In vitro *Cellular and Developmental Biology – Plant*, 47: 26–36.

Normah, M.N., Narimah, M.K. & Clyde, M.M., eds. In vitro *Conservation of Plant Genetic Resources*. Percetakan Watan Sdn. Bdh, Kuala Lumpur, Malaysia.

Upadhyaya, H.D. & Gowda, C.L. 2009. *Managing and Enhancing the Use of Germplasm – Strategies and Methodologies*. http://genebank.icrisat.org/PDF/Section/Section4,5.pdf

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

USDA/ARS. undated. *Taxonomic Information on Cultivated Plants in GRIN-Global*. https://npgsweb.ars-grin.gov/gringlobal/taxon/abouttaxonomy.aspx

Acquisition and Distribution

Alercia, A., Diulgheroff, S. & Mackay, M. 2015. *FAO/Bioversity Multi-Crop Passport Descriptors V.2.1 [MCPD V.2.1]*. Rome: FAO and Bioversity International, 11 p. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/FAOBIOVERSITY_MULTI-CROP_PASSPORT_DESCRIPTORS_V.2.1_2015_2020.pdf

Bioversity 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). https://www.cbd.int/abs/doc/abs-factsheet-faq-en.pdf

Crop Genebank Knowledge Base. 2018a. Distribution. Available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=59&Itemid=208&lang=english

Crop Genebank Knowledge Base. 2018b. Safe transfer of germplasm (STOG). Available at: https://cropgenebank.sgrp.cgiar.org/index.php/management-mainmenu-433/stogs-mainmenu-238

Crossa, J. & Vencovsky, R. 2011. Basic sampling strategies: theory and practice. In: Guarino L, Ramanatha Rao V, Goldberg E, editors. 2011. Collecting Plant Genetic Diversity: Technical Guidelines - 2011 Update. Bioversity International, Rome, Italy. ISBN 978- 92-9043- 922- 926. https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

Eymann, J., Degreef, J., HŠuser, C., Monje, J.C., Samyn, Y. & VandenSpiegel, D., eds. 2010. *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring, Vol. 8*. http://www.abctaxa.be/volumes/volume-8-manual-atbi

Greiber, T., Peña Moreno, S., Ahrén, M., Nieto Carrasco, J., Kamau, E.C., Cabrera Medaglia, J., Oliva, M.J. & Perron-Welch, F. (in cooperation with Ali, N., Williams, C.). 2012. *An Explanatory Guide to the Nagoya Protocol on Access and Benefit-sharing*. IUCN, Gland, Switzerland. xviii + 372 pp. https://cmsdata.iucn.org/downloads/an_explanatory_guide_to_the_nagoya_protocol.pdf

Guarino, L.G., Rao, L.R. & Reid, V. 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB international. https://www.bioversityinternational.org/e-library/publications/detail/collecting-plant-genetic-diversity/

Hay, F.R. & Probert, R.J. 2011. *Collecting and handling seeds in the field*. In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=655

IRRI. undated. *TRANSFER of Plant Genetic Resources for Food and Agriculture*. In: Crop Genebank Knowledge Base. http://www.knowledgebank.irri.org/smta/

Lopez, F. 2015. Digital Object Identifiers (DOIs) in the context of the International Treaty. http://www.fao.org/fileadmin/templates/agns/WGS/10_FAO_gs_activities_ITPGRFA_20151207.pdf

Mathur, S.B. & Kongsdal, O. 2003. *Common laboratory seed health testing methods for detecting fungi*. Bassersdorf, Switzerland.

Maya-Lastra, C.A. 2016. ColectoR, a digital field notebook for voucher specimen collection for smartphones. *Applications in Plant Sciences*, 4(7). https://doi.org/10.3732/apps.1600035

Moore, G. & Williams, K.A. 2011. *Legal issues in plant germplasm collecting* In: Crop Genebank Knowledge Base. https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=669

Ni, K.J. 2009. Legal aspects of prior informed consent on access to genetic resources: An analysis of global law-making and local implementation toward an optimal normative construction. *Journal of Transnational Law*, 42, p.227.

Pence, V.C., Sandoval, J., Villalobos, V. & Engelmann, F., eds. 2002. *In vitro* collecting techniques for germplasm conservation. IPGRI Technical Bulletin No 7. Rome. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/technicalbulletin7.pdf

Pence, V.C. & Engelmann, F. 2011. Collecting *in vitro* for genetic resources conservation. In L. Guarino, V.R. Rao & E. Goldberg. Collecting plant genetic diversity: technical guidelines. 2011 update. Rome, Bioversity International. https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/collecting

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 02. Assessing a population for seed collection.* http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/02-Assessing-population.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 03. Seed collecting techniques*. http://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/03-Collecting-techniques.pdf

Royal Botanic Gardens, Kew. 2014. *Millennium Seed Bank technical information sheet 04. Post harvest handling*. http://www.anayglorious.in/sites/default/files/04-Post%20harvest%20handling%20web_0.pdf

Smith, R.D., Dickie, J.B., Linington, S.H., Pritchard, H.W. & Probert, R.J., eds. 2003. *Seed conservation: turning science into practice*. Kew, UK, Royal Botanic Gardens

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

Way, M. 2003**.** Collecting Seed from Non-domesticated Plants for Long-Term Conservation. In: R.D. Smith, J.D. Dickie, S.H. Linington, H.W. Pritchard & Probert, R.J. (eds.), *Seed Conservation: turning science into practice*. Royal Botanic Gardens, Kew, UK. pp. 163-201.

Way, M. 2011. Crop Genebank Knowledge Base. *Collecting and recording data in the field: media for data recording.* https://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=659

In vitro culture and Slow-growth storage

Badr-Elden, A.M., Nower, A.A., Ibrahim, I.A., Ebrahim, M.K.H. & Elaziem, T.M.A. 2012. Minimizing the hyperhydricity associated with *in vitro* growth and development of watermelon by modifying the culture conditions. *African Journal of Biotechnology*, 11(35):8705-8717. http://www.academicjournals.org/article/article1380809020_Badr-Elden%20et%20al.pdf

Benson, E.E., Harding, K., Debouck, D., Dumet, D., Escobar, R., Mafla, G., Panis, B., Panta, A., Tay, D., Van den houwe, I. & Roux, N. 2011. Refinement and standardization of storage procedures for clonal crops - Global Public Goods Phase 2: Part I. Project landscape and general status of clonal crop *in vitro* conservation technologies. System-wide Genetic Resources Programme, Rome, Italy. http://hdl.handle.net/10568/66354

Cassells, A. C. & Doyle-Prestwich, B. 2009. Contamination Detection and Elimination in Plant Cell Culture. *Encyclopedia of Industrial Biotechnology*, pp. 1–14.

Chin, H.F. 1996. Strategies for conservation of recalcitrant species. In Normah, M.N., Narimah, M.K. & Clyde, M.M., eds. In vitro *Conservation of Plant Genetic Resources*, pp. 203–215. Kuala Lumpur.

Jones, A.M.P. & Saxena, P.K. 2013. Inhibition of Phenylpropanoid Biosynthesis in Artemisia annua L.: A Novel Approach to Reduce Oxidative Browning in Plant Tissue Culture. *PLoS One* 8(10). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3792072/

Leifert, C. & Cassells, A.C. 2001 Microbial hazards in plant tissue and cell cultures. In vitro *Cellular & Developmental Biology*, Vol. 37 (2):133-138. https://www.researchgate.net/publication/226332164_Microbial_hazards_in_plant_tissue_and_cell_cultures

Leva, A.R., Petruccelli, R. & Rinaldi, L.M.R. 2012. Somaclonal variation in tissue culture: a case study with olive. In Recent Advances in Plant *In Vitro* Culture, Rinaldi L (ed). DOI: 10.5772/52760

Murashige, T. & F. Skoog. 1962. A revised medium for rapid growth and bio assays with tobacco tissue culture. Physiologia Plantarum, 15: 473–497. http://priede.bf.lu.lv/grozs/AuguFiziologijas/Augu_audu_kulturas_MAG/literatura/03_Murashige%20Scoog1962.pdf

Nwauzoma, A.B. & Jaja, E.T. 2013.A review of somaclonal variation in plantain (*Musa* spp): mechanisms and applications Journal of Applied Biosciences 67:5252-5260. http://www.m.elewa.org/JABS/2013/67/8.pdf

Onuoha, I.C., Eze, C.J. & Unamba, C.I.N. 2011. *In vitro* Prevention of Browning in Plantain Culture. *OnLine Journal of Biological Sciences* 11(1):13-17 http://thescipub.com/pdf/10.3844/ojbsci.2011.13.17

Pijut, P.M., Woeste, K.E. & Michlet, C.H. 2011 Promotion of Adventitious root formation of difficult-to-root hardwood tree species. In: J. Janick (ed) Horticultural Reviews, Vol 38, Wiley-Blackwell https://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_2011_pijut_002.pdf

Rajasekharan, P.E. & Sahijram, L. 2015. *In vitro* conservation of plant germplasm. In: Bahadur, B., Rajam, M.V., Sahijram, L. & Krishnamurthy, K.V. eds. 2015. *Plant Biology and Biotechnology: Volume II: Plant Genomics and Biotechnology* (pp. 417-443). Springer, New Delhi.

Reed, B.M., Paynter, C.L., Denoma, J. & Chang, Y. 1998. Techniques for medium- and long-term storage of *Pyrus* L. genetic resources. Plant Genetic Resources Newsletter 115:1-5.

Rival, A., Ilbert, P., Labeyrie, A., Torres, E., Doulbeau, S., Personne, A., Dussert, S., Beulé, T., Durand-Gasselin, T., Tregear, J.W. & Jaligot, E. 2013. Variations in genomic DNA methylation during the long-term *in vitro* proliferation of oil palm embryogenic suspension cultures. *Plant Cell Rep*, 32:359–368. DOI 10.1007/s00299-012-1369-y

Rojas-Martinez, L., Visser, R.G.F. & De Klerk, G-J. 2010, The hyperhydricity syndrome: waterlogging of plant tissues as a major cause. Propagation of Ornamental Plants, 10(4):169-175. https://www.researchgate.net/publication/241869171_The_hyperhydricity_syndrome_Waterlogging_of_plant_tissues_as_a_major_cause

Schellenbaum, P., Mohler, V., Wenzel, G. & Walter, B. 2008. Variation in DNA methylation patterns of grapevine somaclones (*Vitis vinifera* L.) *BMC Plant Biology* 8:78. DOI 10.1186/1471-2229-8-78

Scowcroft, W.R. 1984. Genetic variability in tissue culture: impact on germplasm conservation and utilization. International Board for Plant Genetic Resources. Report (AGPG:IBPGR/84/152), Rome, IT.

Sedlak, J., Zidova, P. & Paprstein, F. 2018. Slow growth in vitro conservation of fruit crops. In III International Symposium on Plant Cryopreservation, 1234: 119-124.

Sharma, P.K., Trivedi, R. & Purohit, S.D. 2012. Activated charcoal improves rooting in *in vitro* derived *Acacia leucophloea* shoots. International Journal of *Plant Developmental Biology*, 6 (Special Issue 1) 47-50. http://www.globalsciencebooks.info/Online/GSBOnline/images/2012/AAJPSB_6(SI1)/AAJPSB_6(SI1)47-50o.pdf

Sharma, S.K., Bryan, G.J., Winfield, M.O. & Millam, S. 2007. Stability of potato (*Solanum tuberosum* L.) plants regenerated via somatic embryos, axillary bud proliferated shoots, microtubers and true potato seeds: a comparative phenotypic, cytogenetic and molecular assessment. Planta 226:1449–1458 DOI 10.1007/s00425-007-0583-2.

Sobhakumari, V.P. 2012 Assessment of somaclonal variation in sugarcane. *African Journal of Biotechnology*, 11(87):15303-15309. Available online at http://www.academicjournals.org/AJB

Van den houwe, I., De Smet, K., Tezenas du Montcel, H. & Swennen, R. 1995. Variability in storage potential of banana shoot cultures under medium term storage conditions. Plant Cell Tissue and Organ Culture 42:269-274 https://link.springer.com/article/10.1007%2FBF00029998

Van den houwe, I., Panis, B., Arnaud, E., Markham, R., & Swennen, R. 2006. The management of banana (*Musa* spp.) genetic resources at the IPGRI/INIBAP genebank: the conservation and documentation status, In: Segers, H., Desmet, P. & Baus, E., eds. *Tropical Biodiversity: Science, Data, Conservation Proceedings of the 3rd GBIF Science Symposium*, 18-19 April 2005, Brussels, BE. pp. 143-152. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/bananapublication_proceedings.pdf

Recycling and Rejuvenation

Chandra, S., Bandopadhyay, R., Kumar, V. & Chandra, R. 2010. Acclimatization of tissue cultured plantlets: from laboratory to land. *Biotechnology letters*, *32*(9), pp.1199-1205.

Chandra, S., Rajib, B., Vijay K., & Ramesh, C. 2010. Acclimatization of tissue cultured plantlets: from laboratory to land. *Biotechnology letters* 32, no. 9 (2010): 1199-1205.

Debergh, P. C. 1991. Acclimatization techniques of plants from *in vitro*. In: SHS Acta Horticulturae 289: *International Symposium on Plant Biotechnology and its Contribution to Plant Development, Multiplication and Improvement 289*, pp. 291-300. 1991.

Debergh, P. C. & Zimmerman, R. H. (eds). 1991. *Micropropagation Technology and Application*, Springer, Dordrecht

Hazarika, B. N. 2003. Acclimatization of tissue-cultured plants. *Current science*, 85, (12):1704-1712.

Lucia, G., Castiglione, M.R., Turrini, A., Ronchi, V.N. & Chiara. G. 2011. Cytogenetic and histological approach for early detection of "mantled" somaclonal variants of oil palm regenerated by somatic embryogenesis: first results on the characterization of regeneration system, *Caryologia*, 64:2, 223-234, DOI: 10.1080/00087114.2002.10589787

Marin, J. A. 2001. High survival rates during acclimatization of micropropagated fruit tree rootstocks by increasing exposures to low relative humidity. In: *I International Symposium on Acclimatization and Establishment of Micropropagated Plants 616*, pp. 139-142.

Menendez-Yuffa, A., Barry-Etienne, D., Bertrand, B., Georget, F. & Etienne, H. 2010. A comparative analysis of the development and quality of nursery plants derived from somatic embryogenesis and from seedlings for large-scale propagation of coffee (*Coffea arabica* L.) Plant Cell, *Tissue and Organ Culture*, 102(3):297-307. http://publications.cirad.fr/une_notice.php?dk=556398

Rani V. & Raina, S.N. 2000. Genetic fidelity of organized meristem-derived micropropagated plants: a critical reappraisal. In Vitro *Cellular and Developmental Biology Plant* 36:319-330. DOI:10.1007/s11627-000-0059-6

Rajeskharan, P.E. & Sahijram, L. 2015. *In vitro* conservation of plant germplasm. In: BirBahadur et al. (eds.) *Plant biology and biotechnology: Volume II: Plant genomics and biotechnology*, Springer, New Delhi https://www.researchgate.net/publication/278900645_In_Vitro_Conservation_of_Plant_Germplasm

Read, P. E. & Preece, J. E. (eds.). 2013. SHS Acta Horticulturae 988: V International Symposium on Acclimatization and Establishment of Micropropagated Plants, Nebraska City, NE, USA, 186 pp.

Reed, B.M. & Tanprasert, P. 1995. Detection and control of bacterial contaminants of plant tissue cultures. A review of recent literature. *Plant Tissue Cult. Biotechnol*., 1:137-142. https://www.researchgate.net/publication/222714440_Detection_and_control_of_bacterial_contaminants_of_plant_tissue_cultures_A_review_of_recent_literature

Sandoval, J.A., Côte, F.X. & Escoute, J. 1996 Chromosome number variations in micropropagated true-to-type and off-type banana plants (Musa AAA Grande Naine cv.). In Vitro-*Plant*, 32 (1):14-17. https://link.springer.com/article/10.1007/BF02823007

Characterization and Evaluation

Alercia, A. 2011. *Key characterization and evaluation descriptors: methodologies for the assessment of 22 crops*. Bioversity International 602 p. https://cgspace.cgiar.org/handle/10568/74491

Bioversity International. 2007. *Bioversity Technical Bulletin No. 13: Developing crop descriptor lists. Guidelines for developers.* https://www.bioversityinternational.org/index.php?id=244&tx_news_pi1[news]=1053&cHash=03f5fd26b4bf10a47e6e0ca712ac4610

Bioversity International. undated. *Descriptors*. https://www.bioversityinternational.org/e-library/publications/descriptors/

Bioversity International. 2018. *Crop descriptors and derived standards*. https://www.bioversityinternational.org/fileadmin/user_upload/about_us/news/publications/List_of_Descriptors_Titles_2018.pdf

FAO. 2011. *Pre-breeding for Effective Use of Plant Genetic Resources*. http://www.fao.org/elearning/#/elc/en/course/PB

Thormann, I. 2015. Predictive characterization: an introduction. Paper presented at Regional Training Workshop, 13 April 2015, Pretoria, South Africa. http://www.cropwildrelatives.org/fileadmin/templates/cropwildrelatives.org/upload/sadc/project_meetings/Lectures_Predictive_characterization_pre-breeding/Introduction_Predictive_Characaterization_Thormann.pdf

Thormann, I., Alercia, A. & Dulloo, M.E. 2013. *Core descriptors for* in situ *conservation of crop wild relatives v.1*. Bioversity International, 28 p.

Thormann, I., Parra-Quijano, M., Endresen, D.T.F., Rubio-Teso, M.L., Iriondo, M.J. & Maxted, N. 2014. *Predictive characterization of crop wild relatives and landraces Technical guidelines version 1*. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Predictive_characterization_guidelines_1840.pdf

Molecular Characterization and Evaluation

Arif, I.A., Bakir, M.A., Khan, H.A., Al Farhan, A.H., Al Homaidan, A.A., Bahkali, A.H., Sadoon, M.A. & Shobrak, M. 2010. A Brief Review of Molecular Techniques to Assess Plant Diversity. *International Journal of Molecular Sciences*, 11(5): 2079–2096. https://doi.org/10.3390/ijms11052079

Ayad, W.G., Hodgkin, T., Jaradat, A. & Rao, V.R. 1997. *Molecular genetic techniques for plant genetic resources*. Report on an IPGRI workshop, 9–11 October 1995, Rome, Italy. Rome, Italy, IPGRI, 137 p. http://www.bioversityinternational.org/fileadmin/bioversity/publications/Web_version/675/begin.htm

Bretting, P.K. & Widrlechner, M.P. 1995. Genetic markers and plant genetic resource management. *Plant Breeding Reviews*, 13:11–86.

D'Agostino, N. & Tripodi, P. 2017. NGS-Based Genotyping, High-Throughput Phenotyping and Genome-Wide Association Studies Laid the Foundations for Next-Generation Breeding in Horticultural Crops. *Diversity*, 9(3): 38. https://doi.org/10.3390/d9030038

de Vicente, M.C. & Fulton, T. 2004. *Using molecular marker technology in studies on plant genetic diversity*. Rome, Italy, IPGRI, and Ithaca, New York, USA, Institute for Genetic Diversity. https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/Molecular_Markers_Volume_1_en.pdf

de Vicente, M.C., Metz, T. & Alercia, A. 2004. *Descriptors for genetic markers technologies*. https://www.bioversityinternational.org/e-library/publications/detail/descriptors-for-genetic-markers-technologies/

Govindaraj, M., Vetriventhan, M. & Srinivasan, M. 2015. Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances: An Overview of Its Analytical Perspectives. In: *Genetics Research International*. https://www.hindawi.com/journals/gri/2015/431487/

Jia, J., Li, H., Zhang, X., Li, Z. & Qiu, L. 2017. Genomics-based plant germplasm research (GPGR). *The Crop Journal*, 5(2): 166–174. https://doi.org/10.1016/j.cj.2016.10.006

Jiang, G.-L. 2013. Molecular Markers and Marker-Assisted Breeding in Plants. In: Andersen, S.B. *Plant Breeding from Laboratories to Fields*. IntechOpen, Denmark. https://doi.org/10.5772/52583

Kaçar, Y.A., Byrne, P.F. & da Silva, J.A.T. 2015 Molecular Markers in Plant Tissue Culture In: Floriculture, Ornamental and Plant Biotechnology: Advances and Topical Issues (Vol 11), Edition 1, Chapter 57, Eds JAT da Silva pp444-449 Publisher, Global Science Books

Karp, A., Kresovich, S., Bhat, K.V., Ayad, W.G. & Hodgkin, T. 1997. *Molecular tools in plant genetic resources conservation: a guide to the technologies*. IPGRI Technical Bulletin No. 2. Rome, IPGRI.

Keilwagen, J., Kilian, B., Özkan, H., Babben, S., Perovic, D., Mayer, K.F.X., Walther, A., Poskar, C.H., Ordon, F., Eversole, K., Börner, A., Ganal, M., Knüpffer, H., Graner, A. & Friedel, S. 2014. Separating the wheat from the chaff – a strategy to utilize plant genetic resources from *ex situ* genebanks. *Scientific Reports*, 4: 5231. https://doi.org/10.1038/srep05231

Kilian, B. & Graner, A. 2012. NGS technologies for analyzing germplasm diversity in genebanks. *Briefings in Functional Genomics*, 11(1): 38–50. https://doi.org/10.1093/bfgp/elr046

Laucou, V., Lacombe, T., Dechesne, F., Siret, R., Bruno, J.P., Dessup, M., Dessup, P., Ortigosa, P., Parra, P., Roux, C., Santoni, S., Varès, D., Perós, J.P., Boursiquot, J.M. & This, P. 2011. High

throughput analysis of grape genetic diversity as a tool for germplasm collection management. *Theoretical and Applied Genetics*, 122(6): 1233–1245.

Mishra, K.K., Fougat, R.S., Ballani, A., Thakur, V., Jha, Y. & Madhumati, B. 2014. Potential and application of molecular markers techniques for plant genome analysis. *International Journal of Pure & Applied Bioscience*, 2(1): 169–188.

van Treuren, R. & van Hintum, T. 2014. Next-generation genebanking: Plant genetic resources management and utilization in the sequencing era. *Plant Genetic Resources*, 12(3): 298–307.

Documentation

Ougham, H. & Thomas, I.D., 2014. *Germplasm databases and informatics. Plant Genetic Resources and Climate Change*, pp.151-165. CAB International, CPI Group, UK.

Painting, K.A, Perry, M.C, Denning, R.A. & Ayad, W.G. 1993. *Guidebook for genetic resources documentation*. Rome, Italy, IPGRI. https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Guidebook_for_genetic_resources_documentation_432.pdf

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

Bretting, P.K. 2018. 2017 Frank Meyer Medal for Plant Genetic Resources Lecture: Stewards of Our Agricultural Future. Vol. 58 No. 6, p. 2233-2240.

Fu, Y.-B. 2017. The vulnerability of plant genetic resources conserved *ex situ*. *Crop Science*, 57(5): 2314. https://doi.org/10.2135/cropsci2017.01.0014

International Potato Center. 2014. CIP Training Manual. 1. Tissue Culture. http://cipotato.org/wp-content/uploads/2014/07/Tissue.pdf

IPGRI/CIAT (IPGRI/International Center for Tropical Agriculture). 1994. Establishment and operation of a pilot *in vitro* active genebank. Report of a CIAT-IBPGR collaborative project using cassava (Manihot esculenta Crants) as a model. Cali, Colombia, IPGRI and CIAT.

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 during genebank operations to be considered are presented below.

Acquisition

Risk	Risk Control/Mitigation
Diversity of the source population is not adequately represented in the collected sample	Develop and follow agreed collecting plan
Taxonomic misidentification	Include taxonomist in collecting team and hire genebank staff trained in taxonomy Take herbarium vouchers and photos for verification by experts
Mislabeling/loss of labels	Firmly attach one label to collecting bag; include another label inside the collecting bag
Transcription errors	Consider use of mobile devices Data validation
Loss of viability during collecting missions/transport leading to reduced longevity	Timely transfer to controlled conditions Appropriate post-harvest handling according to propagule maturity, prevailing environmental conditions and phytosanitary conditions

In vitro Culture and Slow-Growth Storage

Risk	Risk Control/Mitigation
Reduced propagule longevity	Appropriate media and storage conditions, including disease management
Mixing/mislabeling of samples	Careful labeling to avoid mixing Use computer-generated barcoded labels to minimize errors
Stored sample falls below viability or quantity thresholds	Ensure that documentation system includes automated tools to monitor viability and inventory and flag up accessions requiring recycling

Recycling and Rejuvenation

Risk	Risk Control/Mitigation
Loss of adaptive alleles due to selection pressures	Appropriate media and recycling conditions Rejuvenate under controlled environmental conditions
Misidentification of sample	Check container and pot labels; use bar codes

Characterization/Evaluation (*in vitro*)

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Check container labels while collecting data

Characterization/Evaluation (greenhouse or field)

Risk	Risk Control/Mitigation
Poorly recorded, unreliable data	Well-trained staff Appropriate statistical design Selection of appropriate locations for planting Appropriate cultural practices Mobile devices to record field data Data validation by curator and/or documentation officer
Misidentification of sample	Use of check accessions/varieties Check plot labels while collecting data Check plot and pot labels prior to sowing and harvesting

Distribution

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Ship the fastest means possible

Safety duplication

Risk	Risk Control/Mitigation
Mixing/mislabeling of samples	Careful packaging to avoid mixing Labels inside and outside Use computer-generated barcoded labels to minimize errors
Viability loss due to delayed or damaged shipments	Ship the fastest means possible