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System Level Review of Genebank Costs and Operations
September 2020

Paper 5: Genebank essential operations

Table of Contents

1. Overview 1
1.1 Range of activities: Essential operations 2
1.2 Crop species biology: Different crops have different needs 3
1.3 Rate of operation 4
1.4 Size and location of collection 8

2. Learning from technical reviews 9
2.1 Operations 9
2.2 Infrastructure 11

3. Working under One Genebank Platform 12
3.1 Working as a community 12
3.2 Reaching and sustaining performance targets 16
3.3 Boundaries of essential operations 17

4. Critical questions to be addressed by the GCO Panel 22

This paper was prepared by the Crop Trust to describe genebank essential operations and the technical background to determining genebank costs. The data presented are sourced from annual technical reports, technical review reports and discussions with genebank managers.

1. Overview

Genebank costs are incurred by the use of facilities, equipment, personnel, supplies, travel, institutional services and overhead. All of these costs, of course, may be minimised by restricting genebank activity, limiting the distribution of materials and foregoing active monitoring or regeneration of accessions. Activity can be minimized to the extent that the only cost incurred relates to the space that seed containers or germplasm take up in a storage chamber. However, whether this can be called a *genebank* is debatable since seeds held in such conditions will have a very limited lifespan and purpose.

In simple terms, the genebanking process follows a defined set of steps from the introduction of a sample of seeds to its storage and, from there, to its retrieval for monitoring, distribution and use. Best practices in carrying out these steps are framed by genebank standards (FAO, 2014) and are based as much as possible on empirical data concerning the longevity of different species and seed batches in storage. The introduction of new materials, distribution to users and the age or viability of seeds in storage are the three main factors that set the pace of genebank activity. Well processed and packaged seeds in optimal storage conditions may remain viable for several decades. It is only when seed supply is short, or viability decreases, that the need for regeneration is triggered, initiating the same processes that were undertaken when the accession was first introduced into the collection: planting out, characterisation, harvesting, threshing, drying, health and germination testing, weighing, counting, packing, etc. Regeneration is an expensive activity and introduces opportunities for

mistakes, misidentification and genetic drift. Most genebanks should, therefore, limit regeneration as much as possible, and try to optimize processes to maximise the longevity of seed viability in storage. This is easier said than done: seed longevity remains an actively researched (if under-resourced) area with much still to be learned about seed dormancy and the effects of post-harvest treatment on behaviour in storage, especially for wild species and less well-researched crop species.

The processes in clonal crop collections are entirely different. Because seeds are not or cannot be stored, the plants are reduced to growing tips and placed on a medium that slows down growth as much as possible. The plantlets outgrow the test tubes in which they are contained within 6-24 months, depending on the crop, and the tissue is then manipulated by hand to reduce it to the growing tips again – a process named "subculturing". Some tissue cultures are conserved like this for decades but eventually they become weakened and require a different level of rejuvenation, which like seed regeneration, involves growing full plants again either in the field or in a greenhouse. Other than the regular need for subculturing, there are other very significant constraints to conserving germplasm in tissue culture that mean only the best resourced genebanks are able to successfully maintain such collections on a large scale in the long term. Facilities with excellent controlled aseptic conditions and a strict hygiene regime are critical to prevent outbreaks of ever-present bacteria, mites or other pests and pathogens. Extensive disease testing for any incoming or outgoing cultures is also a priority since there are a multitude of diseases borne in plant tissue as opposed to the seed, especially viruses. The CGIAR genebanks are among only a dozen or so major tissue culture collections worldwide that are successfully fulfilling a plant conservation objective, and among even fewer that are distributing internationally.

While the processes described above are generally applicable to genebanks worldwide, there are notable differences between genebanks and their management that impact on outputs and costs. In determining an appropriate budget for a genebank, the answer will be shaped by the following factors:

- Range of activities (including standards adhered to)
- Crop species biology
- Rate of operation
- Size and location of collection

This paper considers these factors in turn.

1.1 Range of activities: Essential operations

The "essential operations" of a genebank are the minimum activities that must be undertaken without which the security of the collections and their use are at risk. Crop Trust and genebank managers defined the activities for inclusion as "routine operations" (later renamed "essential operations"), as part of the costing study.[1] The activity definitions were further refined, reviewed and agreed by the genebank managers in 2015 and are listed in Annex 1. USDA follow a very similar prioritization of activities for genetic resource management. Overall, these operations are therefore well understood and accepted and by carefully defining essential operations we have been able to make an argument for "protected" funding not tied to short-term projects. The costing of essential operations also provides a target for the funding required from the Crop Trust endowment mechanism to ensure that supported genebanks can, at least, carry out the critical functions of conserving accessions and making them available on request.

[1] Hawtin, G., Shands, H., MacNeil, G., 2011. The cost to the CGIAR Centers of maintaining and distributing germplasm: Proposal to the Fund Council for financial support to the CGIAR Center genebanks. Consortium Board of Trustees.

However, there are boundary areas that remain challenging to draw not least because the technologies, partners, and users influencing these activities are changing (e.g. information management, characterisation) (See Section 3.3). Several important genebank activities are purposefully missing from this list of essential operations. Collecting, evaluation, molecular characterisation, imaging, introduction of accessions into cryopreservation and conservation research are highly worthwhile pursuits for improving efficiency and developing collections, but they are not included as essential operations because genebanks can and do function without these activities. Funding will be needed for these activities if the genebanks are to continue playing a role in research and contributing actively to the conservation and use of crop diversity.

The costing study of 2011 recognised the need to provide additional funding to support so-called "one off" activities, and likewise the CGIAR System Council in 2015 supported "Option 2" of the Genebank Options Paper that proposed additional activities to promote use, support germplasm health units and ensure policy engagement. We now have an opportunity to again reconsider what are essential operations for funding and what genebank activities should be a priority for additional support.

1.2 Crop species biology: Different crops have different needs

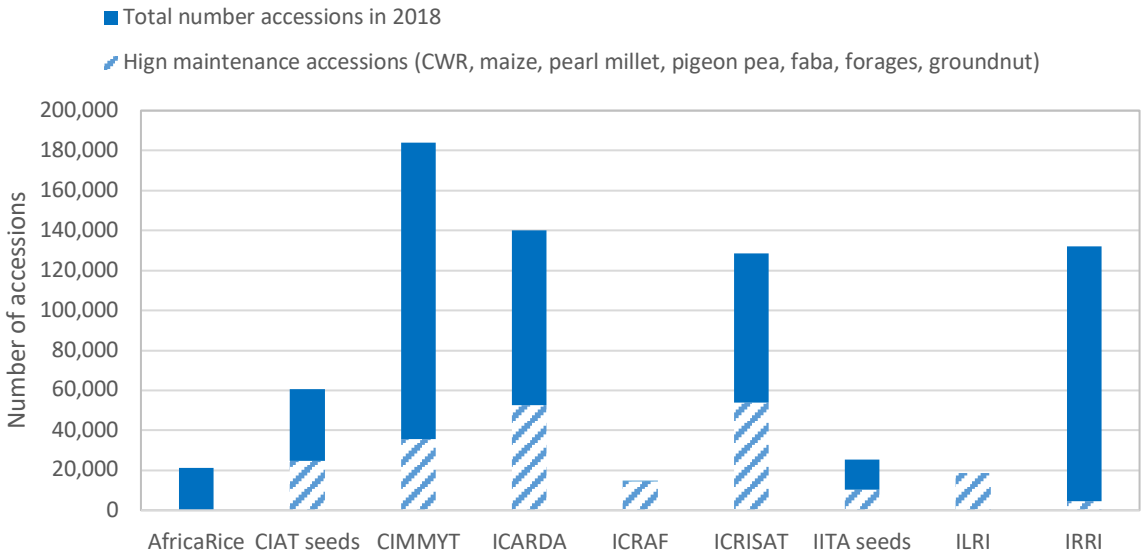
The biology of the crop species has an impact on management needs, particularly for the processes of regeneration and germination testing. ICARDA has illustrated what can be achieved in terms of large-scale regeneration, managing to plant out and harvest more than 20,000 accessions in one season. But this is only possible because a large part of the accessions being regenerated consisted of self-pollinating species such as barley, wheat, chickpea and lentil. For wild species and crops that cross-pollinate, controls must be put in place to isolate accessions from one another. This involves the timely bagging of inflorescences or separation in isolation cages. Some forages depend on insect pollination and require the introduction of bees. Added to this, wild species are likely to produce relatively few, small seeds or exhibit shattering where seeds disperse widely onto the ground, requiring more careful management at harvest and processing. Some exhibit dormancy and have unique needs to induce germination. Of all the seed crops managed by the CGIAR genebanks, the trees species pose the greatest challenge in combining all of the aspects of wild species plus also requiring both considerable space for planting out and time (years) to set seed. The range of crop species managed by the CGIAR genebanks is displayed in Table 1 with darker shading indicating increasingly challenging management. The diversity of crop species managed in a genebank adds to the complexity. However, all of the genebanks manage at least some difficult species or accessions (Figure 1) and it appears that beyond a certain threshold number of accessions, the staff capacity required to manage diverse and difficult crops may plateau (see Paper 1).

Table 1. Crop classification indicating difficult crops to manage (darker shade shows increasing difficulty)

	Category	Crops
1	Self-pollinated cultivated cereal	Wheat, barley, rice, small millets
2	Self-pollinated food legume	Most beans, cowpea, chickpea, lentil, pea & others
3	Self-pollinated wild cereal	Wild relatives of crop type 1
4	Cross-pollinated cultivated cereal	Maize, sorghum, pearl millet
5	Cross-pollinated wild cereal	Wild relatives of crop type 2
6	Cross-pollinated food legume	Grasspea, faba bean, pigeon pea, some beans
7	Cross-pollinated forages, wild species	Forages, trees, wild potato & sweetpotato, groundnut

8	Clonal	Banana, cassava, potato, sweetpotato, yam, Andean roots and tubers

Figure 1. Numbers of accessions of difficult to manage seed crops, compared to the total number of accessions



Data source: Annual technical reports submitted in the online reporting tool (ORT)

1.3 Rate of operation

Essential operations continue annually at a rate dictated by the individual capacity and needs (and backlogs) of the genebank and its users. Although one might expect to see a relationship between certain triggers and rates of operation (such as high acquisition or distribution rates), in fact, the factors affecting the rate of genebank operation appear to be much more complex. Availability of land for planting, staff capacity, annual budget and other factors all play a role.

On average, the CGIAR genebanks (seed collections only) are actively monitoring (i.e. viability testing) approximately 10% of their total holdings annually (Table 2 and Figures 2, 3 & 4) and undertaking other operations at a slightly lower rate. This suggests that each accession is monitored very roughly every 10 years, which does comply with the FAO genebank standards that state that seed accessions held at -18°C should be tested every 10 years if a more appropriate interval cannot be determined empirically. Indeed, studies on the behaviour of individual crop species in storage suggests that this rate can be reduced significantly in several cases.

The CGIAR genebanks are planting out accessions for regeneration and/or multiplication[2] approximately every 12.5 years. If the status of the collection is stable and adequately safety duplicated, if there are minor backlogs and viability and seed stocks are well maintained, the rate of regeneration and multiplication should be limited. Looking at the number of accessions processed per year at IRRI, as a genebank that has sustained performance targets for eight years, the levels or regeneration and multiplication are low, but the rate of viability monitoring is high because some stocks are relatively old, and viability is being monitored closely in order to detect any potential

[2] Regeneration and multiplication are frequently confused. In the annual reporting to the Genebank Platform, “regeneration” refers to planting out of accessions due to their viability (or health) declining below acceptable thresholds and “multiplication” refers to planting out accessions to increase seed because stock numbers have declined below acceptable thresholds or because of special requests from users.

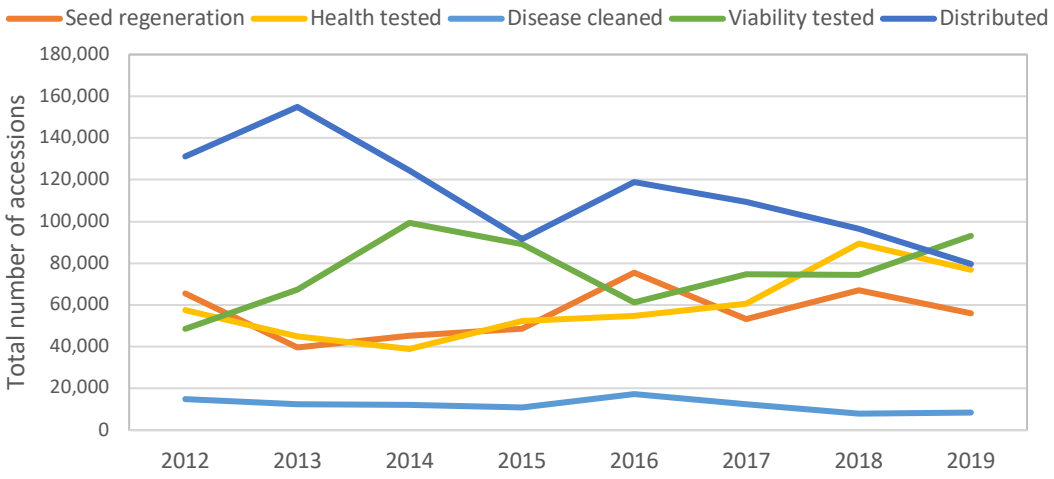
decline (Figures 4 & 5). If a significant number of accessions were to decline below viability thresholds, IRRI would need to increase rates of regeneration.

Table 2. Average annual rate of operation between 2012 and 2019 (source: online reporting tool (ORT[3]))

Operation	Average number of accessions	Average rate (% total collection)
Seed regeneration & multiplication	56,318	8
Health tested	59,397	8
Disease cleaned	12,072	2
Viability tested	75,943	10
Distributed	113,306	15

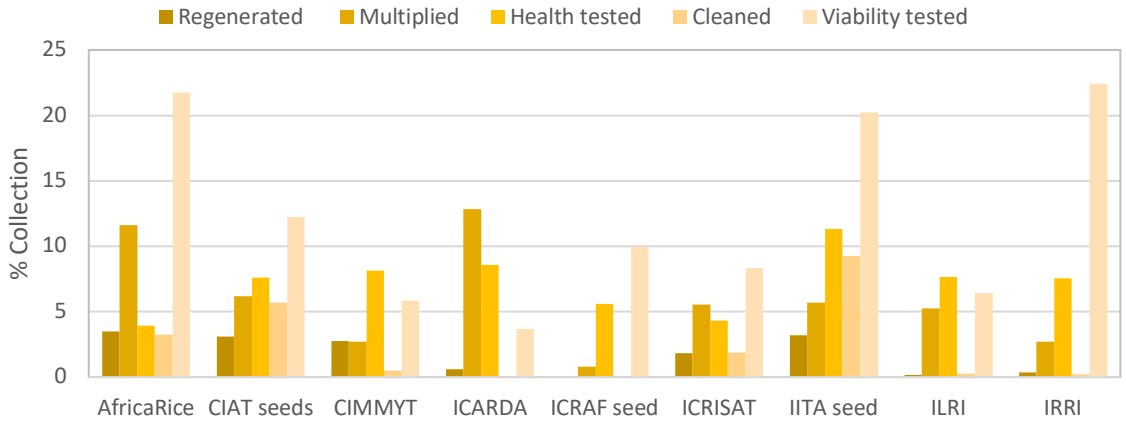
Data source: Annual technical reports submitted in the online reporting tool (ORT)

Figure 2. CGIAR total numbers of accessions processed annually between 2012 and 2019



Data source: Annual technical reports submitted in the online reporting tool (ORT)

Figure 3. Average rate of operation (% total accessions processed) in seed genebanks between 2012 and 2019[4]

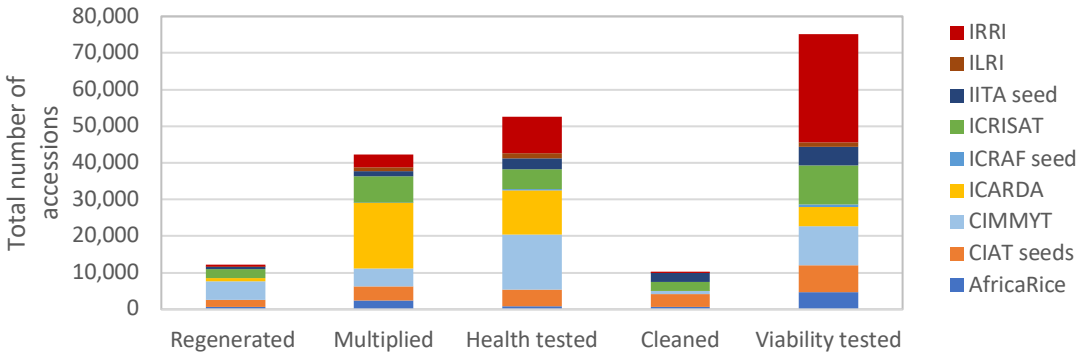


Data source: Annual technical reports submitted in the online reporting tool (ORT)

[3] CGIAR genebanks have been reporting to the Crop Trust annual accession numbers and operation rates in an online reporting tool since 2012

[4] CIP also holds a small seed collection. However, the data for these collections have not been consistently compiled.

Figure 4. Average annual number of accessions processed in seed genebanks between 2012 and 2019



Data source: Annual technical reports submitted in the online reporting tool (ORT)

A small survey of comparable genebanks also suggests that rates of regeneration may be sustained at a lower level than are currently reported by the CGIAR (see Paper 1, Section 3, Figure 19).

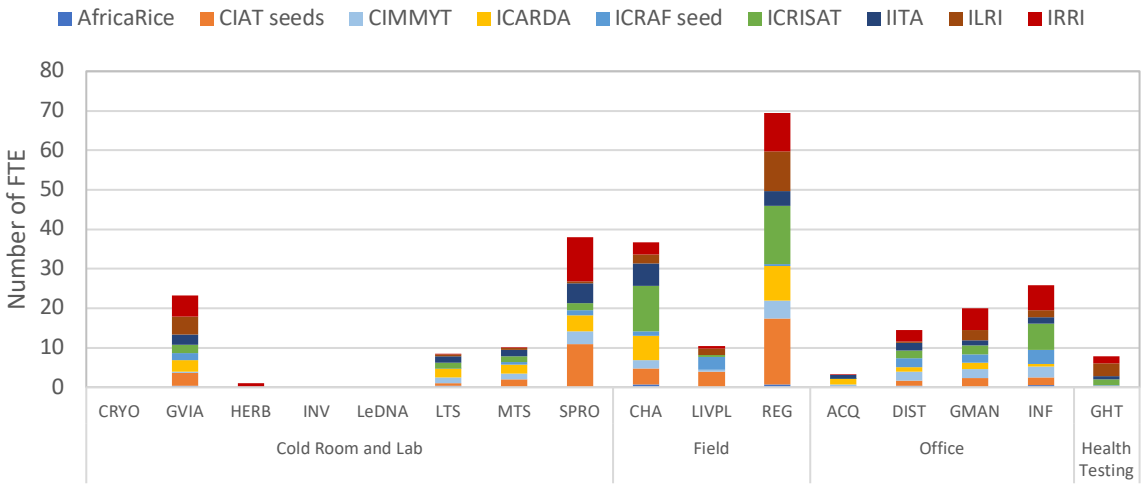
Currently, there is a heightened level of activity as genebanks attempt to reach performance targets. The initiation of the Genebanks CRP introduced quantitative performance targets for the physical and legal availability of collections and their safety duplication (Annex 2). An initial assessment of the status of the collections managed by the CGIAR against these performance targets in 2013 revealed a wide range of situations; all but one of the genebanks had considerable backlogs of seeds that required regeneration, testing, and processing in order to become readily available for use. Additional funding from CGIAR, Crop Trust and other donors has been directed to tackle these backlogs and reach performance targets of 90% availability and safety duplication. AfricaRice and ICARDA, in particular, have managed extraordinary rates of operation in the process of reconstituting their collections. In ICARDA's case, from safety deposits retrieved from the Svalbard Global Seed Vault.

As mentioned in Section 1, regeneration and multiplication together are the most costly activities for seed collections, taking up the most staff time (Figure 5), they also trigger other genebank activities: characterisation, viability testing, seed processing, etc. By contrast, in clonal crop collections, staff time is mostly taken up in monitoring, cleaning and subculturing the tissue cultures (Figure 6).

Given appropriate financial support, many opportunities exist to invest in conservation research and automation to reduce the rates of operation and ultimately the costs at least of essential operations. For instance, each of the following actions theoretically results in halving staff time required for viability monitoring:

- Doubling time interval between viability tests (5 to 10 years or 10 to 20 years)
- Halving the number (e.g. by bulking) of seed lots being stored
- Limiting monitoring to one storage form rather than two (e.g. medium-term storage and not long-term storage).

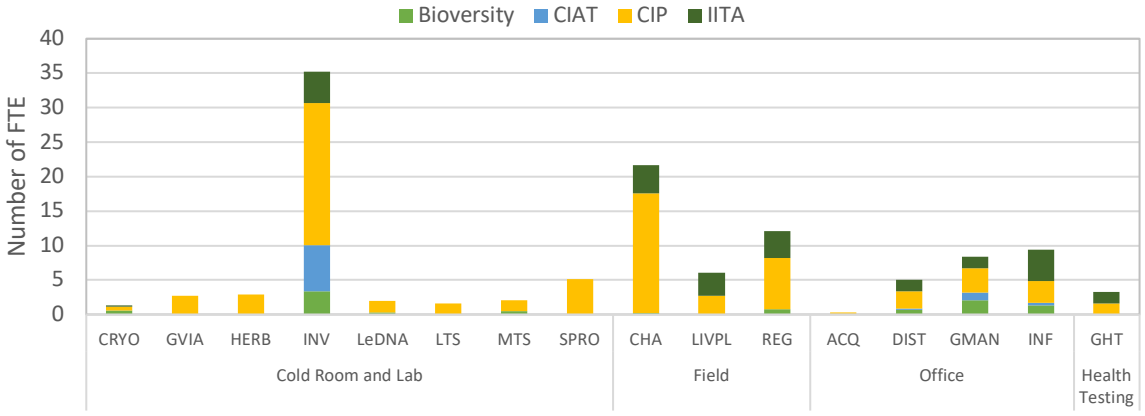
Figure 5. Number of staff full time equivalents (FTE) dedicated to essential operations to manage seed collections



Notes: CRYO=Cryopreservation; GVIA=Germination testing (or viability testing); HERB=Herbarium; INV= InVitro; LeDNA= Leaf DNA Herbarium; LTS=Long-term storage; MTS=Medium-term storage; SPRO= Seed processing; CHA=Characterization; LIVPL=Live Plants; REG=Regeneration/Multiplication; ACQ=Acquisition; DIST=Distribution; GMAN=Administration and management; INF=Information and data management; GHT=Germplasm health testing.

Data source: Genebank costing reviews 2017-2020

Figure 6. Number of staff full time equivalents (FTE) dedicated to essential operations to manage clonal crop collections



Notes: CRYO=Cryopreservation; GVIA=Germination testing (or viability testing); HERB=Herbarium; INV= InVitro; LeDNA= Leaf DNA Herbarium; LTS=Long-term storage; MTS=Medium-term storage; SPRO= Seed processing; CHA=Characterization; LIVPL=Live Plants; REG=Regeneration/Multiplication; ACQ=Acquisition; DIST=Distribution; GMAN=Administration and management; INF=Information and data management; GHT=Germplasm health testing.

Data source: Genebank costing reviews 2017-2020

However, genebank staff require confidence, time and empirical data to make significant procedural changes. Some progress has been made but more should be done. Similarly for automation, since 2015 IRRI has been piloting automated seed sorting. Previously, tens of trained staff were employed to manually sort good seed from bad for storage. In 2016, a custom-made robotic sorter was developed and installed by a Dutch company, SeQSo. The automated sorter is trained to recognise good from bad seed for each individual accession. Once trained, it can run day and night sorting eight accessions at a time. The piloting period has been critical to work out for which accessions and quantities of seed the automated sorter successfully processes accessions (without requiring as much

human input as if nothing had been sorted at all). Lengthy interactions with the Dutch company and periods of downtime while problems, software and equipment are improved were inevitable. The automation works well when there is a large quantity of relatively uniform seed and trials have shown that up to 24 temporary staff may no longer need to be hired for seed sorting. However, genebanks normally deal with small quantities of diverse seed, so there are certain accessions and phenotypes, including wild rice and varieties with coloured pigments, that remain better sorted by hand. Still, without such lengthy piloting, collaboration with the private sector and trial and error, genebanks will not make progress in understanding where automation is useful. It is an appropriate objective for a global role model like the CGIAR with its large specialized collections to blaze a trail in improving seed storage longevity, processes and automation.

The story for clonal crop collections is more challenging to describe, with each of the four CGIAR Centres that manage tissue culture collections using different approaches. Not one of the collections may be considered to be in an optimal state nor to have reached performance targets. In fact, they have shown to be highly vulnerable under current lockdown conditions. The one most significant factor that may be said to influence costs and rates of operation relates to the level to which the collection is conserved in different forms, including whether seed (mostly crop wild relatives) and field collections are conserved. All four genebanks have safety duplicates intended only for emergencies in either tissue culture or in cryopreservation. In addition, IITA, Alliance-CIAT and CIP (but not Alliance-Bioversity) replicate their collections partially or fully in actively managed collections in the field or in the screenhouse for various reasons. CIP also manages an extensive program of seed production and conservation of mostly wild species, which none of the other genebanks do. The standard of health testing in operation also has a major impact on costs but is not entirely captured in the staff number and costs of essential operations since much of the cost of GHUs is borne in other budgets.

The four genebank managers have formed a Community of Practice (COP) on clonal collections and are considering ways of achieving greater alignment. Given the status of the collections and the need for larger scale cryopreservation, this exercise will undoubtedly identify additional needs and costs (Table 4).

1.4 Size and location of collection

There are limits imposed by facilities, space, field sites, isolation cages and staff that dictate how much can be processed, planted or stored at one time. As implied in the above sections these limitations are crop dependent – approximately 14 cereal accessions can be conserved to every two forage accessions or single clonal crop accession according to per accession costs (see Paper 1). However, while a collection of greater size does appear to be more costly to run, the number of staff required to run large collections (>100,000 accessions) is not significantly greater than that required for smaller collections (<50,000 accessions) (see Paper 1, Section 2.2.1). There appears to be significant economies of scale to be gained from higher throughput.

Most genebanks, with one or two exceptions, appear to have been effective and flexible in ramping up operations and accommodating the gradual increase in the size of collections (1-2% per year). Several genebanks (AfricaRice, CIMMYT, CIAT, ICARDA) have identified new and/or additional field sites or refurbished existing sites to accommodate increased regeneration or specific accessions in the collection, sometimes setting up temporary arrangements with farmers. Similarly, temporary labour has been scaled up or down to deal with different rates of operation. Probably a more significant limiting factor is the capacity to maintain the workflow and deal with harvested seeds once they are returned to the lab and going through the cycle of health testing, cleaning and processing, etc. Some relaxation of standards has been necessary, in certain documented cases, to process seed and get it into storage as soon as possible. Capacity in cold rooms has also been built when needed.

These points are relevant when considering the global role of the CGIAR genebanks, their future expansion and the services they may provide to researchers and breeders. They also relate to arguments for rationalizing collections. A policy framework introducing dynamic curation and the possibility of archiving accessions has been developed under the Genebank Platform and is the process of being reviewed by appropriate bodies in the FAO before being reviewed and approved at a System level in the CGIAR. This is significant in that it allows CGIAR genebank managers to make justified decisions to place specified accessions into formal curation categories that demand less intensive management. The hoped-for outcome will be to enable the genebank staff and managers to focus resources and time on the most unique and diverse parts of the collections. Significant gains in staff time and costs as a result of these changes are unlikely to be realised for easy-to-manage crop species. However, for forages, trees and clonal crops the possibilities are much more interesting. Alliance-CIAT and ILRI are planning to reduce substantially the fully curated parts of their respective tropical forages collections (See box pp 13-15).

The locations of the CGIAR genebanks came about by historical opportunity and, in most cases, are coincident with the geographical centres of diversity for the crops concerned. In the early years of the CGIAR, no doubt, the locations of the genebanks played a role in the continued growth and use of the collections. However, demand for most CGIAR mandate crops is global and the concentration of target users does not correspond with centres of diversity. Indeed, for several crops the research, breeding and use of genetic resources is occurring in distant regions to where the collections are currently conserved. (e.g. cassava, sweetpotato, sorghum, banana etc). Distribution figures portray consistent trends towards high germplasm distribution in genebanks' host countries and regions. There is certainly an opportunity for the CGIAR genebanks to reach out to a wider range of potential users further afield.

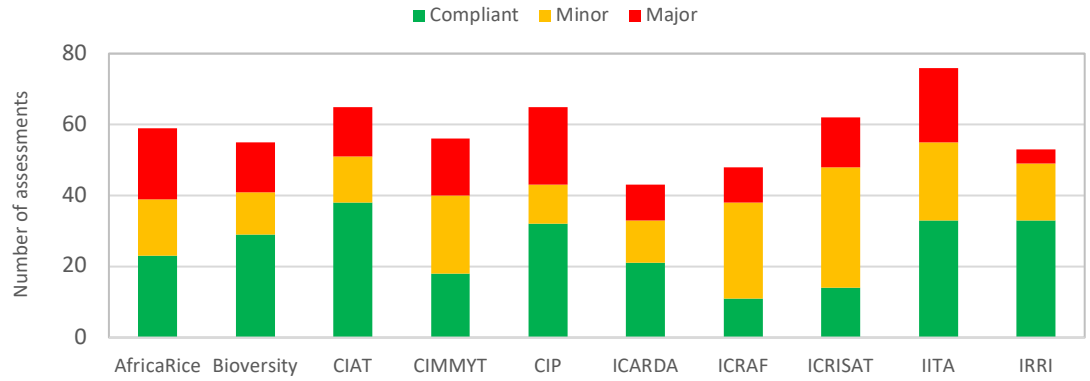
2. Learning from technical reviews

2.1 Operations

Two phases of external genebank review have taken place in the course of the past nine years. The findings of the first phase reviews resulted in individual action plans for each genebank focussing on improving the status of the collections with respect to performance targets, and also in several program level initiatives, including the establishment of performance targets and genebank quality management systems (QMS). The second phase of external review started in 2019 and finished in May 2020. This phase of review included auditing and validation of documented standard operating procedures (SOPs) for key operations and a much more intensive, in-depth assessment of genebank procedures. A standard format for assessing procedures was adopted for all reviews[5]. Figure 7 presents the number of assessments at each genebank falling into one of three categories: (1) compliant, (2) minor observation or (3) major observation.

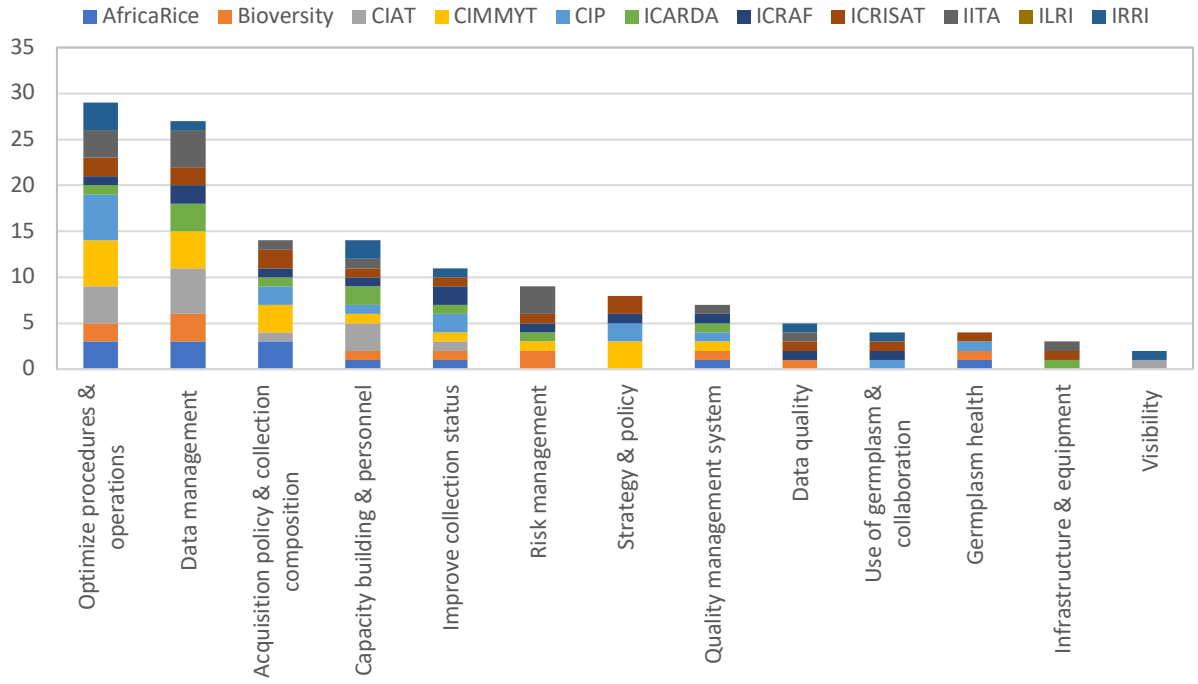
[5] Due to lockdown measures, AfricaRice and ICRAF reviews were undertaken remotely using the same format. The ILRI review was cancelled.

Figure 7. Number of assessments from 2020 genebank reviews that showed processes were compliant, or involved minor or major observations



Data source: Genebank technical reviews 2019-2020

Figure 8. Number of recommendations in 2020 reviews relating to different critical areas of genebank operations



Data source: Genebank technical reviews 2019-2020

A total of 137 recommendations were made relating to findings, frequently shared by multiple genebanks. Unsurprisingly given the focus of the reviews, the majority of observations concerned the need to optimize procedures (Figure 8). Such findings were often well known to the genebank staff. Although many achievements are evident, genebank managers face the challenge that the collections are old and have grown over time without documentation and sometimes without strategic direction. The current status of both the germplasm and associated data is heavily influenced by the legacy of data and data management, decisions and well-entrenched procedures that are taking time to change.

Table 3 summarizes some of the typical observations that came up in reviews (See also Paper 1, Annex 2). Examples include viability monitoring being overly burdensome because of the need to manage

excessive numbers of seed lots in storage or because of poor historical monitoring and recording of viability or dormancy behaviour; the limitations of field sites and lack of adaptation of parts of the collection to available sites; and the need to confirm genetic identity of accessions, remove unnecessary duplicates or rebalance the composition of collections. A significant deficiency in data management and quality is particularly evident. Current systems are totally inadequate to deal with 21st century expectations. While impressive progress has been made in adopting hand-held devices, barcoding and digital object identifiers (DOIs), most genebanks still use multiple data management systems and software that only loosely relate to one another, have limited capacity to incorporate data coming in from hand-held devices being used in the field or lab, and provide inadequate access to curators or managers for quality checking and monitoring, and even less capability for reporting on the collection in its entirety. With an aim to address this seemingly relentless challenge, a more radical approach was adopted in 2020 to scale up the development of a single database software, GRIN-Global Community Edition (GGCE), for ultimate adoption by all genebanks for the management of all collections. We expect adoption and use of GG-CE for entire collection management by nine genebanks by the end of 2021.

Table 3. Common elements of recommendations in the 2020 reviews

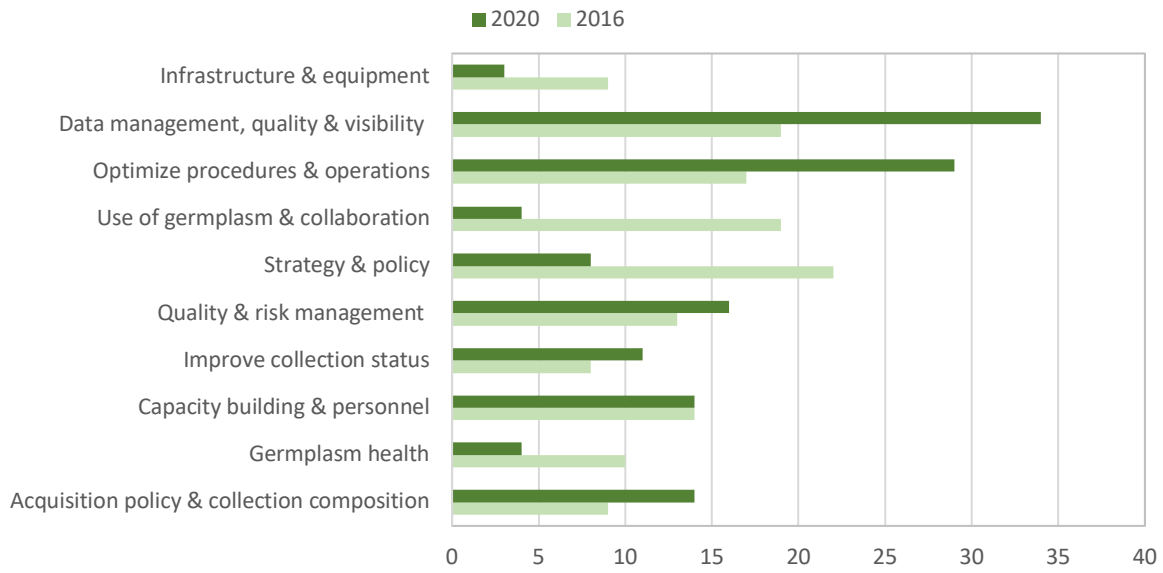
Thematic area	Common recommendations
Optimize procedures & operations	Optimise viability monitoring load (reduce seed lots), improve regeneration sites/success/process, dormancy research, improve identity verification process, tissue culture protocols, storage containers, management of most original sample.
Data management	Management of, manipulation and access to key data for curation, improve recording of/interpretation of data, data gathering, barcoding, validation and software/database development.
Acquisition policy & collection composition	Acquisition policy especially relating to breeders' materials, collection composition, rationalization.
Capacity building & personnel	Training in specialist areas, teamwork, clarity of responsibility/accountability, staff retention issues, delegation.
Improve collection status	Take action to improve status challenging parts of collection, status of availability or safety duplication (esp. wild spp, neglected seed lots, difficult crops, trees)
Risk management	Alarm systems, evacuation plans and exits, risk & disaster plans, dealing with liquid Nitrogen.
Strategy & policy	Use of SMTA, strategic use of resources, recovery of costs, alignment with partner genebanks.
Quality management system	Improve SOPs, question suitability of ISO.
Data quality	Complete passport data, provide more characterisation data
Use of germplasm & collaboration	Analyse/follow up with users, proactive distribution, strategic partnership
Germplasm health	Reduce complexity of, improve or review GHU processes.
Infrastructure & equipment	Repairs, electricity, gradient of cleanliness in in vitro labs.
Visibility	Online experience in search genebank accessions, web site visibility

2.2 Infrastructure

An important area of improvement over the past few years has been the state of the genebank facilities and equipment. A considerable investment has been made, not only by the CRP and Platform,

but also by the Centres themselves, to build and equip the genebanks. AfricaRice, CIAT, CIP, ICARDA, IITA, ILRI and IRRI have constructed entire new buildings or floors and all 11 genebanks have built or refurbished new labs, cold rooms or extensions. Further, IRRI and CIMMYT have invested in automation of germination testing and IRRI of seed sorting. The automated germination testing is still in a pilot phase. However, the automated seed sorting capability has resulted in evident efficiencies, although it is not clear how transferable these are to more diverse collections than that of IRRI.

Figure 9. Number of recommendations from two phases of review in 2016 and 2020



3. Working under One Genebank Platform

Since 2012, all genebank operations have been funded and overseen under one program, first the Genebanks CRP then the Genebank Platform, both coordinated by the Crop Trust with direction from a part-elected Management Team. The Genebank Platform is structured in three Modules (Conservation, Use and Policy), and includes the participation of the CGIAR germplasm health units (GHUs) and a unit dedicated to international genetic resources policy led by the Alliance-Bioversity. The basis and advantages of working together under one program in this way are described in the Paper 2.

3.1 Working as a community

There is no doubt that the CGIAR genebank managers have benefited from working as a community and sharing experiences in defining, documenting, implementing and improving essential operations and other genebank activities. There are several examples where a practice developed in one genebank has been adopted by another (e.g. silver nitrate added to tissue culture to extend longevity, use of barcoding equipment, data management processes and software, approaches to cryopreservation, etc). Such exchanges, of course, do not necessarily depend on a funded program, although the implementation of improvements generally does. However, centralized monitoring of the Program has allowed the establishment of performance targets, strengthening of QMS, regular audits and external reviews all tailored to genebanks (rather than research programs), and to the gradual development of common CGIAR genebank and phytosanitary standards and approaches.

In addition, Platform or program funding has supported a number of collective activities that has involved experts or Centres leading the way in specific activities to the benefit of the group as a whole, including the following:

- Gap analysis and collecting with national partners
- Database software development
- Research on seed quality management and phytosanitary issues
- Genotyping accessions and analysing the resulting data
- Developing tools to develop germplasm subsets
- Representation within CGIAR and to outside bodies such as the Plant Treaty and the International Plant Protection Convention.

The genebanks remain autonomous and the management of operations, risks, improvements and change is under the control of the individual genebank managers and the senior management within the individual Centres. Addressing review recommendations and guidance from experts or peers is similarly at their discretion. However, the managers make up a coherent, highly collaborative group and many achievements have been possible in working together, dating as far back as the Systemwide Genetic Resources Program in the early 2000s.

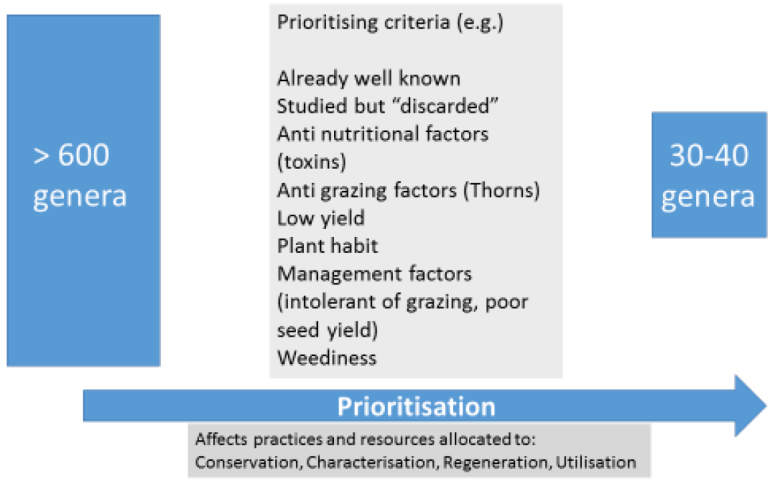
However, efforts to align or achieve rationalization between different genebanks maintaining the same crops have had little tangible outcome, with the exception of CIAT and ILRI where the tropical forages community have been actively inputting into the curation of the collections (see box pp.13-15). Also, in 2020, the CGIAR genebanks with stations based in West and Central Africa have initiated an effort to seek more integration and engagement in the region. Further efforts to address similar issues were planned in 2020 but the lockdown on travel has prevented further work.

The following crop collections are held in multiple Centres:

- Wheat (and barley) at CIMMYT and ICARDA
- Cassava at CIAT and IITA
- Banana at Bioversity and IITA
- Chickpea at ICARDA and ICRISAT
- Rice at AfricaRice and IRRI
- Tropical forages at CIAT and ILRI
- Maize at CIMMYT and IITA

Taking stock of CIAT and ILRI Forage Genetic Resources:
Harmonizing operations between the two germplasm collections

The external technical reviews of ILRI genebank (in 2012) and CIAT (in 2013) recommended to reduce accession redundancy of the tropical and sub-tropical forages (TSTF) collections. The *Global Strategy for the Conservation and Utilisation of Tropical and Sub-Tropical Forage Genetic Resources* developed in 2015 through the Crop Trust, also suggested greater efficiency in conservation, including through the curation of species by prioritization.



Box 1. Prioritization of genera and species to enable better focus on conservation and utilization of taxa more likely to contribute to livestock production and environmental benefits.

A consultant, Brigitte Maas, was hired to assist the genebanks in implementing the strategy and aligning the operations at either genebank. She found both significant similarities and differences in the two genebanks, and several opportunities to increase efficiency:

- All accessions should be stored under long-term storage (LTS) in base collections and safety duplicated at least at one different site. While CIAT is well advanced, ILRI has yet to achieve this;
- ILRI needs to ensure freedom of quarantine-relevant pathogens in its germplasm;
- Both CIAT and ILRI need to ensure that their germplasm can be internationally exchanged and make headway towards removing regulatory or policy barriers when they can't;
- Principles of Dynamic Curation should be applied as soon as possible with differential management (fully, partially and non-curated accessions) of the germplasm, first according to species prioritization, and secondly on an accession basis, considering the most original sample (MOS), demand for distribution, and membership in a core collection or any other subset of elite accessions;
- Avoid redundancy in accessions between the two genebanks – inactivate redundant accessions – potentially reducing the CIAT collection by ~ 16% or the ILRI one by ~ 20% of accessions; assign lead species per Centre;
- Adjust (mostly reduce) targeted seed quantities for conservation ('availability') and distribution to the numbers defined by FAO/Genebank Platform (especially ILRI);
- Reduce the number of seed lots associated with individual accessions – diminishing subsequent workload in viability monitoring and seed health testing (especially ILRI);
- Use data mining for gaining more insights into the collections—e.g. seed germination with passport and characterization data; historic characterization and evaluation data; collecting (passport) data; distribution data—will lead towards more efficient management and greater germplasm utilization;
- Establish strategic partnerships for enhanced utilization of TSTF germplasm – establish an advisory group to the TSTF collections to re-connect with upstream and downstream R&D user communities; promote use of the Tropical Forages Database selection tool;

- Carry out species prioritization for differential management (i.e. dynamic curation) of species/accessions according to their use potential, their membership in a core collection or other defined subset (e.g. 'best bets' for specific agro-ecologies).

To provide a more detailed example, the highlighted similarities and differences of one genebank operation– in this case viability testing – for the same crop are described as follows:

	CIAT	ILRI
Initial viability test	Before entering LTS, if in temporary MTS within max. 2 years (1,000 accessions/yr on average, 1,178 acc. in 2017)	Within 2 years of MTS (92-368 seed lots tested within 2 years)
Seeds per test	100 seeds: 50 x 2 reps; statistical tolerance *P ≤ 0.10*	80 seeds: 20 x 4 reps; statistical tolerance *P ≤ 0.05*
Acceptability threshold	*Legumes*: ≥ 85% normal seedlings; if in-adequate germination complemented with Tetrazolium test *Grasses* (Tetrazolium test): ≥ 85% caryopses positive	*Wild legumes*: ≥ 65% normal seedlings *Crop legumes*: ≥ 85% normal seedlings *Grasses*: ≥ 65% normal seedlings
Scarification	*Legumes:* Mechanical using scalpels/drill for individual seeds *Grasses:* usually no treatment; floret cleaning to obtain caryopses in special cases only	*Legumes:* Mechanical: hot water, hot wire, sandpaper, scalpel, nail cutter (for hard seed), H2SO4; Physiological dormancy: Cold (5-8°C) or high temperature, H_2SO_4, KNO_3, GA3 *Grasses* (preparation): Floret cleaning to obtain caryopses
Germination method (plating)	*Legumes:* • Small seed on paper (paper rolling method) • Large seed on sterile sand outdoors	*Legumes:* • Small seed on top of paper in Petri dish • Large seed on top of paper in a plastic box or between paper (rolling method) *Grasses:* On agar medium with KNO3 (0.2%) in Petri dish; cold treatment(optional)
Germination environment	Germination chambers in the lab: 12 hrs light/dark at 25°C 8 hrs light/16 hrs darkness, 35/20°C Outdoors on shelves under ambient conditions	Germination chambers in the lab: Tropical grasses: 12 hrs light/dark at 30°C day/ 20°C night Temperate grasses: 8 hrs light/16 hrs darkness, 15-20°C
Evaluation	Applying ISTA rules *Legumes:* germination checked after 7, 14 and 21 days *Grasses:* Only applying Tetrazolium test, evaluation same day	Applying ISTA rules *Legumes:* germination checked after 24 hrs (sandpaper scarified), 4 and 14 days *Grasses:* germination checked during 3-35 days once/ week
Data capture	In real time; using bar codes	In real time on tablet
Dealing with failures	• Statistical tolerance – repeat test • Germination under threshold – regenerate again (or after max. 2 yrs in MTS, retest seed)	• Statistical tolerance – repeat test • Germination under threshold – retest
Monitoring intervals	• Starting after 5 years • Next tests after 5, then 10 years	• Starting 1/3 of time taken for most forage seeds to reach 65% viability, food-feed crops 85% viability

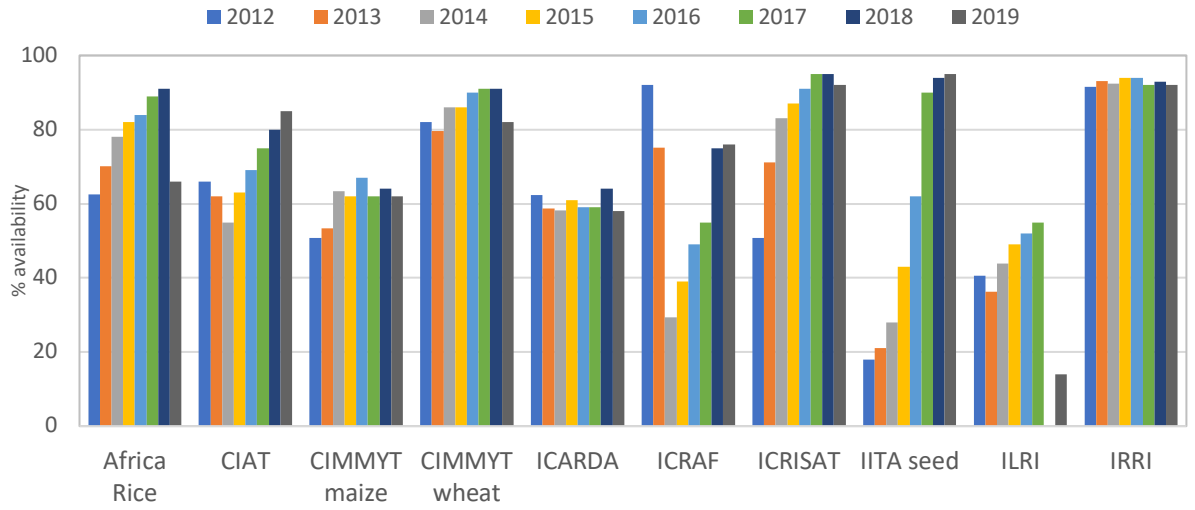
	• If > 90%, in increasingly longer intervals: 15/20 years	• Species without information: every 10 years (wild legumes > 65%, crops) every 5 years (grasses + wild legumes < 65%)
Backlog	Currently testing of 2011-regenerated accessions, 2 years delayed	About 1,700 accessions (~ 10% of the collection) never tested
Viability testing efficiency		
Viability test/ yr (no.)	2 persons year-round, forages every other week, alternating with beans; plus 1 person only scarifying seed almost 6 months/yr: • *Legumes*: 2,600 accessions • *Grasses*: 200 accessions	4 persons during 6 months/year, incl. accessing + scarifying seed: • Overall: 3,000 samples (accession x seed lot)

3.2 Reaching and sustaining performance targets

One of the major justifications of the Genebanks CRP and Platform was to support the raising of standards and optimization of the individual CGIAR genebanks so that they could reach a steady state of operation and be funded through a Long-term Partnership Agreement from the endowment managed by the Crop Trust. The basis for this request for support originated in the identification of several one-off needs in the 2011 Costing Study.

The status of the seed crop genebanks with regard to availability has improved markedly and is presented in Figure 10. Upon achieving final steps towards completing inventorying and restocking exercises, reaching safety duplication targets and archiving accessions, several genebanks will become eligible for LPAs (e.g. AfricaRice, CIMMYT, CIAT seed, ICARDA, ICRISAT, IITA seed)

Figure 10. Status of availability (% of total collection available) of seed collections across years



Data source: Annual technical reports submitted in the ORT.

Several genebanks and most particularly the clonal crop collections are unlikely to reach performance targets by the end of 2021 and consequently additional support will be required for specific genebanks to achieve these goals.

3.3 Boundaries of essential operations

While essential operations are relatively well defined, every genebank functions in a specific context influenced by facilities, assets, staff skills, environment, history, partnerships and other factors. Accommodating different situations brings advantages and effectiveness but leads to unequal allocation of resources. While the core of essential operations is indisputable, the boundary areas can be contentious and need revisiting periodically.

What is most revealing in discussing boundary areas is that genebanks require considerable funding and investment outside of essential operations in order to advance, improve and become more efficient and effective. The genebanks should not be restricted to the passive role of an old-fashioned librarian, responding to requests but with a limited capacity to improve collections or make recommendations or open users' eyes to the value of other, lesser known but potentially game-changing resources. Sustaining essential operations is, no doubt, critical to keeping large, unique, globally important collections healthy and available, but the art of genebanking, as with all conservation activity, is striking a balance between investing in preservation of resources, revealing their value and promoting their sustained use.

Specific boundary areas are summarized in Table 4 for illustration and discussion. Options are provided that describe potential areas where funding could be rationalized but, in most cases, there is a need for more investment in genebank activities beyond essential operations. The potential solutions to dealing with these areas should not be driven by available funding alone and it will be necessary, firstly, to share a common understanding on the following assumptions so that different possibilities for support can be distinguished:

- The Crop Trust will always have to limit the funding it dedicates to LPAs for CGIAR genebanks to the critical operations that ensure conservation and availability of specific crop collections in the long-term. The criteria that it uses to make these decisions will be agreed by the Crop Trust Executive Board. However, this principle should by no means dictate the overall funding provided to the genebanks ("ring-fenced" or not);
- The CGIAR genebanks will require additional funding to that provided in LPAs, not least because a condition of the LPA is for the host institute to provide complementary funding;
- Funding to CGIAR genebanks may come in many forms: in kind contributions, host agreements, cost recoveries, outsourcing, Windows 1 and 2 funding, bilateral projects and program funding;
- Some genebank activities are relevant to develop in collaboration with CGIAR breeders and researchers and therefore may reside optimally in collaborative research projects;
- Nearly all conservation activities and research will lie outside of programmatic CGIAR research areas and will not compete against typical CGIAR research projects. These are the activities that will particularly need to be highlighted by the Panel.

Table 4. Boundary areas and proposed ways of addressing differences in operations between genebanks

Essential operation	Boundary area	Question	Options
Seed crops			
Acquisition & distribution	Acquiring breeding materials & genetic stocks - increasing collection size but not necessarily overall diversity.	➔ Should genebanks be doing more to manage breeders' materials on their behalf?	CURRENT MODEL/USER PAYS: Keep acquisition & curation policies strict. Eliminate breeders' collections unless they pay fully for the costs.

Essential operation	Boundary area	Question	Options
			INCREASE W1&2: Provide allowance to genebanks to support a role to manage breeders' collections on a time-bound basis.
	Multiplication & distribution of larger amounts of seeds	➔ Should users pay to obtain larger germplasm quantities?	**CURRENT MODEL/USER PAYS**: Genebanks continue to distribute only very limited amounts of seed or ask for a cost recovery if they do more. **INCREASE W1&2**: Provide allowance to genebanks to support distribution of larger quantities of seed in specific situations.
	Distribution of germplasm on behalf of all CGIAR using well defined phytosanitary and policy framework	➔ Should genebanks play a larger role in overseeing the distribution of all CGIAR materials, i.e. including nurseries and other outputs of breeding programmes?	**CURRENT MODEL/USER PAYS**: Genebanks remain responsible for the distribution of their collections only. **INCREASE W1&2**: Distribution units are set up in genebanks and potentially in additional target areas with phytosanitary and policy backstopping for and exchange of materials including all germplasm coming from the CGIAR.
Information & data management	Funding for genebank information management is limited and focussed on collection management	➔ How should CGIAR genebanks invest in information management and resources?	**CURRENT MODEL/ESSENTIAL OPERATION:** Genebanks receive fixed funding for data management related to collection management only. Limited additional project funding provided through Platform. **INCREASE W1&2:** Support is provided for a more innovative and expansive role in generating, analysing and making available data on collections to all genebanks, also for website and software development.
Germination or viability testing	Conservation research (seed longevity, dormancy) is not an essential operation but it is funded as a one-off activity under the Genebank Platform. It is	➔ How should CGIAR support the costs of conservation research to improve the efficiency of	**CURRENT MODEL:** Conservation research is not an essential operation. One-off proposals are funded to a limited degree for specific conservation research from Platform funding.

Essential operation	Boundary area	Question	Options
	the key means of improving efficiency and addressing the difficulty of managing many seed collections, especially of crop wild relatives – should CGIAR be doing more?	genebank processes and conservation activities	**INCREASE W1&2:** Build up CGIAR role as leader in conservation research and develop efficiencies through more generous funding for conservation research.
Regeneration, multiplication & characterisation	Rate, cost and success rate of regeneration are divergent among genebanks	➔ How should CGIAR set parameters for covering costs of regeneration?	**CURRENT MODEL:** Genebanks receive funding for current rate of operation plus additional funding to deal with backlogs on a needs' basis. **RATIONALIZE**: Genebanks receive ringfenced funding for capped rate of operation but have access to additional funds for urgent needs.
	Molecular characterisation of genebank collections	➔ How should CGIAR set parameters for covering costs of genotyping of genebank collections?	**CURRENT MODEL**: Molecular characterisation is not an essential operation (exc for some clonal crops). One-off genotyping work is supported to limited degree from Platform funding. **INCREASE W1&2:** Allowance is provided to all genebanks to support the use of genotyping for quality management and for genotyping a limited number of subsets per genebank.
	Phenotyping/evaluation of genebank collections	➔ How should CGIAR set parameters for covering costs of phenotyping work by genebanks?	**CURRENT MODEL:** Phenotyping work is supported with very limited funding outside of essential operations. **INCREASE W1&2:** Support genebanks to carry out "smart phenotyping" in collaboration with breeders.
Seed processing	Automation may be appropriate where throughput is high and diversity is manageable.	➔ How could more be done to innovate in automation?	**CURRENT MODEL:** Piloting and implementation of automation has been possible in 2 genebanks through one-off funding. **INCREASE W1&2:** Specific genebanks are supported to pilot and implement automative systems.

Essential operation	Boundary area	Question	Options
Clonal crops			
Acquisition & distribution	Genotyping for incoming materials to ensure new acquisitions add diversity and are not duplicates	➔ How should CGIAR set parameters for covering costs of genotyping of clonal crop collections?	**CURRENT MODEL**: Support for genotyping upon acquisition is limited to some clonal crop genebanks (Alliance-Bioversity only) **EXPAND ESSENTIAL OPERATION:** New acquisitions are genotyped as a matter of routine – subject to the rest of the collection being genotyped and a reference being available.
	See "Seed crops" for other boundary areas under "Acquisition and Distribution"		
In vitro	Medium term storage of specific crop species should be improved through protocol optimization & research (e.g. sweetpotato, yam)	➔ How should CGIAR support the costs of conservation research to improve the efficiency of genebank processes and conservation activities	**CURRENT MODEL**: Research to improve in vitro conservation protocols not supported. **INCREASE W1&2**: All genebanks receive an allowance to improve protocols
	With time all cultures are susceptible to declining viability and/or somaclonal variation	➔ What is the most cost-effective way of addressing declining viability and somaclonal variation.	**CURRENT MODEL**: No support for researching somaclonal variation or carrying out rejuvenation. **EXPAND ESSENTIAL OPERATION & INCREASE W1&2**: Periodic rejuvenation on a standard basis (based on risk assessment) to become part of defined essential operations. Increase funding for research into somaclonal variation.
Cryopreservation	Research on cryopreservation protocols from proof of concept to development of protocols for large-scale implementation (for crops beyond potato and banana)	➔ How should CGIAR support the costs of cryopreservation research	**CURRENT MODEL**: No funding for cryopreservation research. **INCREASE W1&2:** Substantially increase investment in cryopreservation for crops not yet cryopreserved on a large scale.
	Implementation of cryopreservation for large clonal crop collections.	➔ How should CGIAR support the costs of	**CURRENT MODEL**: Limited funding for one-off costs of gradually cryopreserving

Essential operation	Boundary area	Question	Options
		implementing cryopreservation	banana, potato plus sweetpotato and cassava. **INCREASE W1&2:** Substantially increase investment in cryopreserving collections and accessions not yet cryopreserved.
Lyophilized leaf banks & DNA banks	Freeze dried leaves provide an alternative to live germplasm when only DNA is required or when diseased germplasm cannot be distributed. They can also act as reference material.	➔ How should CGIAR support the costs of conserving lyophilised leaves	**CURRENT MODEL**: Only Alliance-Bioversity supported to conserve and provide lyophilised leaves. **EXPAND ESSENTIAL OPERATIONS**: All genebanks supported to develop, conserve and provide lyophilised leaves.
Conserving crop wild relatives (CWR) as seed	Managing CWR in tissue culture is not ideal. Protocols to produce and conserve crop wild relatives are needed to improve coverage of crop diversity.	➔ To what extent should CGIAR be conserving CWR of difficult-to-conserve crop species	**CURRENT MODEL**: CIP conserves seed at cost (e.g. to produce SWP seed). Other Centres receive limited/no support **INCREASE W1&2:** Alliance-Bioversity/CIAT & IITA also receive funding for seed production and CWR conservation research and implementation.
Live plants collections	Permanent live plant collections (i.e. in field, greenhouse) are justifiable when accessions cannot be held in other forms. Can they be justified for other reasons (e.g. CIP potato, IITA cassava)?	➔ How should the costs of supporting live collections be covered?	**CURRENT MODEL**: Ringfenced funding is provided for whatever collections Centres decide is strategic to conserve. **RATIONALIZED/USER PAYS**: Genebanks receive ring-fenced funding for one primary active conservation form unless clearly justified.
Phytosanitation of tissue culture collections	Various clonal crop collections or parts of collections (e.g. yam, banana, Andean roots & tubers) remain unavailable because of quarantinable pathogens and processes are encumbered by phytosanitary bottlenecks	➔ How can CGIAR make a significant difference to the phytosanitation specifically of clonal crop collections	**CURRENT MODEL**: Limited funding is provided to help support disease diagnostics research and cleaning but major bottlenecks remain **INCREASE W1&2**: CGIAR invests in disease diagnostics research and cleaning to make real headway in removing bottlenecks and making accessions available.

4. Critical questions to be addressed by the GCO Panel

Concluding remarks:

- The essential operations of the 11 CGIAR genebanks are broadly comparable given the current individual approaches and management structure of the genebanks with the exception of some questionable boundary areas (as highlighted in Table 4).
- There are many opportunities to seek efficiencies at both individual genebank level and across the system of genebanks – some of which have been highlighted by technical reviews (see Paper 1, Annex 2), many have also been identified by the genebank managers, including:
    - Investing in conservation research to extend viability monitoring period and reduce the need for regeneration and multiplication;
    - Optimizing procedures:
    - Large-scale cryopreservation for clonal crops and specific recalcitrant seed crops or species;
    - Reaching performance targets and reducing rates of regeneration and multiplication as a result;
    - Rationalizing collections or operations through strategic curation and archiving;
    - Aligning conservation activities and management of same crop collections in different Centres;
    - Sharing resources, expertise, capacity between genebanks in the same region;
    - Developing a more coherent system-level management structure;
    - Seeking opportunities for co-location or merging collections to increase size and throughput;
    - Improving and standardizing methods of recovering costs for institutional services to the genebank.
- In order to explore, plan and implement such efficiencies, specific measures, incentives, funding and management structures or decision-making will need to be established to support genebank managers and staff.
- There are many opportunities to invest in activities that will render the genebanks more effective and promote the use of the collections. We have also highlighted that the CGIAR genebanks have an opportunity to expand their outreach, engagement with potential users and germplasm distribution outside of the host countries and regions in which they are located. Building a network of decentralized multi-crop distribution hubs of different size and capacity, including other genebanks inside or outside the CGIAR, national and private sector partners may be worth exploring.
- Clonal crops, tropical forages, tree and CWR collections require substantial additional support to reach performance targets, cryopreserve collections and improve the effectiveness and security of *ex situ* conservation efforts. Prioritizing these needs will be challenging and should take account of a range of factors including vulnerability of unique diversity, use and cost.

As a final word, I believe it is worth emphasizing that the CGIAR genebanks remain excellent value for money and a unique global resource protected for future generations under an international treaty. The recent MOPAN assessment[6] highlighted six key strengths of the CGIAR, of which only one referred specifically to the work of existing CGIAR CRPs/Platforms. While naming the strength, the assessment also made a recommendation or rather gave a warning, which is highly significant since the CGIAR has done an excellent job of recognising its genebanks but has historically under-resourced and de-prioritised the operation and use of the genebanks. The new One CGIAR Research Strategy represents opportunities but also poses a risk of returning the genebanks to a state of being overshadowed, especially if the long-term conservation activities and services of the genebanks to the world of users

[6] MOPAN. 2019 Performance Assessment of the CGIAR. http://www.mopanonline.org/assessments/cgiar2019/

outside of CGIAR researchers and breeders are not, in the words of the MOPAN assessors, made the most of.

> ***"CGIAR's open intellectual assets and genetic material are a significant global resource, although there is a question of whether the System is making enough of it.",*** *one of CGIAR's six strengths according to the MOPAN Assessment 2020*

Questions to pose to the GCO Panel:

1. Ring-fenced funding for essential operations: is this still possible and an appropriate way to protect the critical conservation and distribution operations of the 11 CGIAR genebanks?

2. Are the defined set of essential operations appropriate? How should we deal with boundary areas?

3. What are the additional activities and/or collective actions that are a priority for support?

4. How should the CGIAR strive for greater efficiency
    A. in operations at individual genebanks and
    B. in the System as a whole?

5. How can we allocate funding more equitably?

Annex 1. Essential operations 2012-2020

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Acquisition	Office	Receiving and processing newly introduced accessions.	1. Contact with providers. Shipping. Unpacking 2. Obtaining plant import permits, risk analysis, entry into country and clearance process 3. Registration and passport data verification and entry 4. Data checking with data provider 5. Ensure legal procedures are covered	1. Gap identification 2. Collecting mission 3. Phenotypic characterisation, multiplication, seed processing and safety duplication for initial storage 4. Disease-indexing/quarantine for initial storage 5. Disease-cleaning for initial storage
Administration and management	Office	Administrative and supervisory tasks to ensure the effective management of the genebank as a whole	**Operation of people management, administration, planning, risk management and networking with peers.** 1. *People management* - Staff supervision and mentoring Planning HR and capacity development 2. *Administration* - Monitoring/analyzing/planning activities Donor reporting and performance indicators Budgeting and monitoring expenditure of genebank budget 3. *Quality assurance* - Monitoring and updating SOPS and risk management strategy 4. *Networking* – Providing feedback to the Treaty Secretariat and FAO Commission Representing the genebank or Genebank Platform in meetings, events or institutional processes Providing expertise and partnership in general	1. General staff meetings and gatherings 2. Training

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Distribution	Office	Sending accessions upon request (e.g., preparation, shipment, etc) or for genebank operations including safety duplication	1. Selection of accessions 2. Communication with requestor (follow up, question answering, advice). SMTA acceptance, import permit receipt, etc. 3. Seed sorting and weighing/tissue culture preparation 4. Labelling and packing 5. Phytosanitary requirement follow-up 6. SMTAs issuance 7. Shipping/mailing 8. Data entry, inventory updates and filing of SMTA/paperwork 9. Follow up on receipt and satisfaction Including safety duplication.	1. Multiplication/regeneration of samples 2. Disease-indexing
Information and data management	Office	Data entering, processing and management (including catalogue preparation).	1. Management of hard copy documentation/field and lab books/collection sheets/MTAs/agreement 2. Database management and data backup including software and source code. Support for barcoding, electronic data capture, etc. 3. Data publication system for external users. Data enquiries. 4. Preliminary data analysis 5. Effective data validation, procedures for data quality assurance 6. Data transfer to other platforms (e.g. Genesys). Migration online of pdf files, digital images, etc. 7. Development for communication with information platforms 8. Online catalogues and ordering system. User surveys	1. Software applications and web development 2. Barcoding software development 3. Training 4. Data entry

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Cryopreservation	Cold Room and Lab	Long-term storage in liquid nitrogen of in vitro material (including seed material where applicable)	1. Germplasm maintenance in liquid nitrogen. Monitoring LN2 supply 2. Cryopreserved sample monitoring 3. Data entry	1. Costs associated with the introduction of new material into cryopreservation
Germination testing (or viability testing)	Cold Room and Lab	Testing of germination rate of existing or newly multiplied accessions.	1. Selection of accessions, inventory check and preparation of lists 2. Germination test before storage including media preparation, removal of sample from storage, dormancy-breaking treatments. Germination counts, observations on abnormal seedlings and tolerance tests 3. Viability monitoring during storage. 4. Data entry	1. Seed processing
Seed processing	Cold Room and Lab	Packing, cleaning and drying of seeds – for storage or distribution	1. Processing, drying, packing, labelling (including barcoding). Fumigation 2. Threshing/mechanical cleaning 3. Seed extraction, washing and cleaning for 'wet' seed. 4. Checking seed purity and quantity 5. Drying operations 6. Moisture content testing 7. Sample sorting 8. Seed packing and labelling 9. Data entry	1. Sample identity check, inc. grow-out 2. Germination test before storage 3. Disease diagnostics before storage 4. Viability monitoring during storage 5. Field health inspections 6. In vitro costs of any kind
Long-term storage	Cold Room and Lab	Conservation of seed accessions in the long-term storage facility. Cold room	1. Maintaining controlled environment access and security systems 2. Sample storage 3. Stock management including monitoring of collections; monitoring of conditions, security and access systems 4. Assigning locations and data entry	1.Items covered by institute service costs 2. Germination viability testing 3.DNA genebanks 4.Seed processing/preparation including packaging 5. Cryopreservation, In-vitro conservation

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Medium-term storage	Cold Room and Lab	Seed/tuber conservation of accessions in medium-term storage for ready dissemination upon request. Cold room.	1. Maintaining controlled environment, access and security systems 2. Sample storage 3. Stock management including monitoring of collections and conditions 4. Assigning locations and data entry	1.Items covered by institute service costs 2. Germination viability testing 3.DNA genebanks 4.Seed processing/preparation 5. Cryopreservation, In-vitro conservation
Introduction of new accessions into cryopreservation	Cold Room and Lab	Process of cryoprocessing new accessions into the collection	1. Selection of clones to be introduced 2. Multiplication and processing of material for cryopreservation 3. Introduction of germplasm into LN2 4. Testing and analysis of success of accession cryopreservation 5. Data entry	1. Maintaining cryopreserved collection 2. Optimization of cryopreservation protocols 3. Wholescale introduction of accessions into cryopreservation on a large scale
In Vitro	Cold Room and Lab	In vitro conservation, sub culturing	1. Introduction into in vitro 2. In vitro seedling monitoring (viability/vigour check, elimination of old culture, contamination) 3. Germplasm subculturing for conservation 4. Germplasm maintenance using slow-growth methods 5. Multiplication of germplasm for distribution/safety duplication 6. Data entry including use of barcodes	1.Disease-cleaning 2. Disease-Indexing 3.Introduction into cryopreservation 4. Rejuvenation/regeneration 5. Research on in vitro protocols
Leaf DNA Herbarium	Cold Room and Lab	Maintenance of collections of lyophilised leaves or other materials for DNA extraction	1. Monitoring and storage of conserved non-reproductive materials	1. DNA extraction 2. Processing of materials into storage

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Characterization	Field	Recording the characteristics of each accession, often conducted during the regeneration process.	1. Selection of accessions and traits for characterization 2. Data collection 3. Observation and recording (including digital images) of morphological characteristics (including in electronic field book) 4. Routine measures to ensure identity and genetic integrity are maintained 5. Data entry into databases 6. All field and material preparation, planting, etc. is included under REG unless characterisation is carried out as a separate operation to regeneration with strong justification. 7. Travel to field sites	1. Identification of duplicates using molecular characterisation except clonal & forages 2. Taxonomic studies 3. Maintenance of herbarium collection. Maintenance of seed herbaria collection. 4. Imaging and maintaining images 5. Molecular characterisation 6. Analysis and formation of core collection and reference sets.
Live Plants	Field	Maintenance of essential collections that cannot be held other than as growing plants	1. Field management/irrigation/pruning 2. Selection of and preparation of material for field. Transfer to field site, planting and labelling (including barcoding) 3. Field inspection for diseases, insects and weeds 4. Processing for planting (cuttings, tubers, sanitation) and propagation 5. Germplasm harvesting (non-perennials) 6. Data entry	1.Activities covered by institutional land management services 2. Characterization 3. Any lab activities (e.g. health testing) 4. Regeneration/multiplication

Category		DESCRIPTION	ACTIVITIES INCLUDED	ACTIVITIES NOT INCLUDED
Regeneration /Multiplication	Field	Producing fresh seeds by planting out seeds for storage or dissemination. May include temporary holding of material in glasshouses and nursery	1. Monitoring/analyzing/planning need for regeneration. Selection of accessions and sites 2. Seed/planting material preparation including scarification. May include greenhouse stage prior to field. Transfer to field site. 3. Field/glasshouse preparation 4. Isolation cages for cross-pollinated species 5. Planting and field management. Inspection for diseases, pests, mixtures and weeds. Recording in central database. 6. Harvesting of seed/tuber/cuttings 7. Data entry 8. Travel to and from field sites (Includes regeneration for introduction of new accessions, multiplication for storage and multiplication for distribution, etc)	1. Characterisation data collection 2. Indexing/sanitation 3. Threshing, cleaning and processing 3. In vitro subculture
Germplasm health testing	Health Testing	Testing of germplasm health, often carried out upon acquisition or during regeneration process.	1. Disease diagnostics before storage and dissemination 2. Post-entry quarantine	1. Cleaning 2. In vitro costs

Annex 2. Performance targets

Indicator	Target
Availability Percentage of collection that is clean of pathogens of quarantine risk, viable, and in sufficient quantity to be immediately available for international distribution from medium-term storage	90% accessions available
Safety duplication For seed crops: % collection held in long-term storage at two locations and also in Svalbard Global Seed Vault (except for tree spp.). For clonal crops: % of the collection held in long-term storage or cryopreservation at two locations or in slow growth conditions *in vitro* at two locations.	90% seed accessions safety duplicated 90% accessions duplicated in *in vitro* or cryopreservation
Data availability Entire collection with minimum passport and/or characterization data online	Passport Data Completeness Index (PDCI) greater than 6
QMS Quality Management System in place	Agreed minimum elements of QMS/ISO are in place: Validated standard operating procedures (SOPs), Restricted access, Barcoding, Staff succession plan, Risk management plan