Global Genebank Partnership

Genebank Review Report

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1 Summary of Review Findings and Recommendations

In the 2017-2025 Strategy, the World Vegetable Center Genebank is described as "the world's largest public collection of vegetable seed for global and local vegetables," with two genebanks, the WorldVeg HQ genebank in Taiwan and the WorldVeg seed repository in Tanzania. The Strategic Objective for the genebank for 2025 was a diverse and well characterized germplasm collection with the vision to be "the World's most-consulted vegetable germplasm collection with fully functioning genebanks in Taiwan and Tanzania entirely backed up to safeguard vegetable diversity for future generations." The placement of the genebank within the Vegetable and Diversity Flagship recognizes and utilizes the collection for crop improvement with its many links to the seed sector. The WorldVeg committed to maintain and expand its collection utilizing international genebank standards/protocols and provide access in line with the ITPGRFA. They would expand phenotyping and genotyping with sharing of data in global platforms and repositories. They recognized that there are many important vegetables globally and regionally so there is a need to prioritize and describe a set of criteria to select crops for breeding. This commitment to global vegetable crop genetic resources conservation and use is a key strength for the WorldVeg genebank system with its two sites in Taiwan and Tanzania. The opportunity to focus on local vegetables regionally is a strength of the two genebank approach. Thus, both collections need to be secured for the long term with secure, sustainable routine operations that ensure conservation and access.

The review of the WorldVeg genebank included baseline responses from both sites, the LTG Business Plan for 2023-2027, background documents shared by both sites, and site visits. The reviewers considered the strengths of each site as well as the opportunities for improvement. The key strength of the Taiwan genebank (TWNGB) is its critical mandate and reputation since the world needs an international collection of vegetable plant genetic resources and WorldVeg is the most appropriate organization with its knowledge, facilities, and international network of users. It was clear from the interactions with staff and their active participation in the review that the staff are motivated, dedicated, and capable, with the potential for growth. The WorldVeg current collection provides a very good basis for being a global vegetable genebank with conservation of important collections significant for food and nutrition security. The TWNGB is on the right track with investments in continuous improvements, safety duplication, newly upgraded genebank facilities, quality management system with documentation/data management/QR codes/SOPs. The genebank is ready to make a leap in the level of operations so now is critical to rethink priorities and embrace quality. The genebank has served as a resource for other genebanks in the region with training and capacity building. There are opportunities for improvement to rationalize routine operations, secure conservation, improve availability, and sustain the genebank for the long term. The main areas for improvement identified were:

- Physical quality of seeds is largely unknown or possibly below standard. Thus, there is a need to prioritize baseline germination testing for the entire collection versus clearing backlog in acquisition of new accessions.
- Reconsider the composition of the collection in terms of redundancies and crop choice.
- Finalize and implement Standard Operating Procedures (SOPs) at all levels and sites.
- Fully integrate GGCE in terms of both data capture and use in monitoring of all routine operations.
- Documentation is sometimes scattered or incomplete so needs to be centralized and completed.
- Optimizing workflow and use of storage rooms and working areas.
- Reconsider the allocation of staff and their responsibilities to improve workflow and address backlogs.
- Financial sustainability needs to be addressed with reduced dependency on projects, which is creating a long term vulnerability on the routine operations of the genebank.

The reviewers concluded that the key strengths of the Tanzania genebank (TZAGB) are its relevance, global mandate, and sustainability being embedded within WorldVeg. It is headed by a manager/leader with vision and knowledge of genebanks, crop diversity, and partnerships. The young, enthusiastic, and dedicated genebank staff have potential for growth and development. There is supportive capacity in infrastructure, administration, and technical backstopping regionally and in HQ. There is a strong link to the user community through projects. The upgrade of the facility and the key importance of the genebank to the region supports the goal to expand the collection. There are some key areas that need

to be a focus for improvement. These are discussed in detail in the report and are the basis for many of the recommendations. The key areas of improvement are:

- Declining quality of seeds in medium-term storage (MTS) with currently no long-term storage (LTS) and limited evidence of safety duplication
- Considerable backlogs in routine operations that are not yet compliant to international standards.
- Greater alignment of the composition of the collection to the mission of WorldVeg

The reviewers have considered these strengths and opportunities for improvement in the development of this report and the recommendations given in Table 1. More specific details of the proposed priority actions are given in the relevant sections of the report.

The reviewers have also considered the recommendations from the previous review of the TZAGB, assessed the status and responded to the actions recommended (Table 2). There is consistency in many of the recommendations for TZAGB in Table 1 and Table 2.

Table 1. List of recommendations

ID	Recommendations	Proposed priority activities to address recommendations	Location
1	Urgently secure accessions of priority crops that are currently at risk of loss of genetic integrity	Storage condition of the current MTS facility should be revised, and the temperature should be reduced to 4-5C° and RH to 15%.	TZA
		All essential documentation (passport and management data) of all the accessions should be compiled in a consolidated file (Excel file) to allow prioritization of accessions for viability testing, shift to LTS, and/or regeneration.	TZA
		Based on the essential documentation, set priority of crops and accessions, and then check the seed MC to ensure that it is within the acceptable range for the crop (3-7% seed MC). If not, the whole accession seed lot/batch must be dried without delay to the accepted standard.	TZA
		Repack the dried seeds for each batch of an accession in two aluminum foil bags and seal them hermetically. Label each bag with the 'Accession Number' and 'Batch Number' and possibly the crop name.	TZA
		Put one foil bag into a box to send either to the Taiwan genebank or another international genebank in the region, such as ILRI in Ethiopia or ICRAF in Kenya or even IITA in Nigeria, as a temporary black box safety duplication and the other kept in TZAGB MTS facility, until the LTS facility is fully operational.	TZA
2	Manage composition of the collection for sustained long term conservation	TWNGB and TZAGB prioritize which crops and accessions to include in the collection for the long term and archive those accessions currently considered of low priority with: ● A thorough assessment of the duplication of its accession in other genebanks utilizing the passport data any other historical information. ● Utilize knowledge of the status of the conservation and availability of the accession in other genebanks to initially reduce the priority for viability testing and regeneration or archive the accession. ● Utilize other criteria, such as priority crop for WorldVeg research programs, seed viability, legal status, or availability of passport information to further identify accessions that have a low priority for the backlogs or could be archived.	TWN/TZA
		The passport data be updated to correct the biological status classification and better reflect the unique nature of most of the accessions conserved.	TWN
		Urgently, all accessions on the red list should be packaged and conserved under LTS conditions to prevent any further deterioration of the seeds.	TWN
		The red list is rationalized taking into account critical available information (e.g. duplication in other genebank, legacy data	TWN

ID	Recommendations	Proposed priority activities to address recommendations	Location
		attached to accession etc.) to determine priority for viability testing and regeneration.	
		Temporary accessions number should be given to newly acquired material, as described in the previous Acquisition SOP (2019), until the genebank ensures that accessions enter the collection after meet the criteria for quality, have sufficient number of seeds, and meet other criteria to make the decision to assign an accession number and include in collection in both sites.	TWN/TZA
3	Improve the monitoring and management of accession identity in seed handling and conservation	Fully utilize QR codes to reduce the risk of loss of identity, enhance monitoring and management of data and carry out operations efficiently through the GCCE management system.	TWN/TZA
		The label used for each package for an accession in the MTS should contain the unique identifier of the accession, which is the Accession Number, and a QR code.	TNZ
4	Address the backlog in viability testing and monitor viability of accessions in base collection	Protocols for viability testing and monitoring frequency for each of the crops/species that are handled by the genebank should be developed and included in the Conservation SOP.	TWN/TZA
		All legacy data on seed viability of accessions should be collated and included in the GGCE database to improve the baseline information for management decisions.	TWN
		Increase capacity to test 6000 accessions annually per year with improved seed viability testing facilities and more staff.	TWN
		Develop a roadmap and longer term plan to address the backlog of viability testing to facilitate decisions on distribution and regenerations.	TWN
		Test all newly acquired and/or regenerated accessions to give a baseline and establish monitoring of viability on a routine basis using crop species specific protocols.	TWN/TZA
		Allocate staff fully to germination/viability testing, provide hands-on training by staff in TWN or other experts who could also advise/verify if methods used are appropriate or if there is need for doing research on improved protocols.	TZA
		Acquisition of appropriate equipment (i.e. two functional germination cabinets with light and temperature control) for viability testing.	TZA
5	Ensure secure, sustainable, and cost effective assessment of germplasm health	Crop Trust should encourage the involvement of WorldVeg in the Germplasm Health Community of Practice of the CGIAR Genebanks Initiative.	TWN
		Reconsider technical aspects of seed health testing such as ● Reduce sample size needed for testing of germplasm health ● Increase length of time for the validity of seed health certificate ● Test the use of bulking instead of individual accessions to reduce seed requirement for each test.	TWN
		Establish a process to allow for reexport of the original seed of introductions that are conserved in the quarantine storage and are currently excluded for entry into Taiwan.	TWN
6	Address regeneration backlog with secure regeneration protocols	Transition to the use of tablets to expand the use of QR codes in the regeneration fields for verification and tracking of accessions during regeneration/multiplication, characterization, harvesting, and post-harvest handling.	TWN
		Monitor longer term performance of each regeneration partner to deliver a consistent supply of high quality seed to reduce the risk of loss of genetic integrity of the accessions.	TWN
		Greater engagement of staff responsible for regeneration in Taiwan and in Tanzania to address the capacity building needs in Tanzania and to develop crop specific protocols in a regeneration SOP.	TZA

ID	Recommendations	Proposed priority activities to address recommendations	Location
		The number and type of mesh cages should be increased to allow for secure regeneration that maintains genetic integrity and seed quality.	TZA
		Address the growing regeneration backlog from new national collections, utilizing the experience from TWNGB, to increase the capacity of the national collecting partners to regenerate/multiply and provide high quality seed with adequate seed quantity.	TZA
7	Improve seed handling facilities for extraction and processing	The efficiency of the extraction process should be improved by upgrading the wet seed extraction facilities with more workspace for inside the processing laboratory as well as the workspace outside with more concreted work areas, outside sinks and workspace, better system to eliminate wastewater, and dedicated shaded areas for the work.	TWN
		Access to the roof drying area should be improved by installing a lift to move the seeds to the roof more efficiently	TWN
8	Secure the conservation and enhance the use of the garlic/shallot collection	Implement one or two of the options to secure the cost effective conservation and enhance use or the garlic or other *Allium* crop collection • Transfer or safety duplicate the *Allium* collection at another genebank, as being currently explored. No investment will be needed for in vitro conservation. • Investment into the cost effective development of the tissue culture facility to facilitate access and long term conservation with virus elimination and improved plant health. • Increase the cost effectiveness for field and in vitro conservation with the expansion of the collection to include more regional diversity of garlic or other *Allium* crops.	TWN
9	Improve seed handling processes and workflows for conservation	The seed MC determination area and quarantine work area should be separated, and seed MC determination conducted in a more secure location close to the drying room and quarantine storage room.	TWN
		The area where seed MC determination is conducted should be controlled to 15%RH.	TWN
		To minimize any exposure of the dried seeds to high moisture outside the drying room, seeds are transported in a closed container (like plastic Tupperware with silica gel in them) from the dryer to the MC determination and the seed packaging area.	TWN
		Seed packs should be vacuum sealed, and the security of the seal checked routinely.	TWN
		Ensure all accessions in MTS and in the new accession room are conserved in LTS conditions (if possible) and the relocation recorded in GGCE to ensure better monitoring.	TWN
		Upright freezers should be acquired and the cold rooms (#9 and 10) \ renovated and fitted with these freezers to be used to conserve distribution packs.	TWN
		Seed packets to be used for regeneration, viability testing and as remnant be conserved in the LTS.	TWN
		If the seed packets are not vacuum packed, the RH of the LTS storage rooms should be set to the international standards of 15±3%.	TWN
		The drying and seed packaging should be done in a RH controlled area next to the LTS cold room.	TZA
		Seed acquisition and temporary holding can take place in the room currently designated as drying room.	TZA
		As in Taiwan, the distribution seed packs from MTS should be stored in individual freezers.	TZA
		Seed bags for conservation should be transferred to the new LTS and the MTS room used solely for seed kit distribution.	TZA

ID	Recommendations	Proposed priority activities to address recommendations	Location
10	Enhance the availability, quality and use of genebank information at both sites with the full implementation of GGCE	Migrate all legacy data to GGCE to allow for its full utilization in more efficient collection management.	TZA/TWN
		Recover as much as possible the legacy passport data from previous databases and other relevant available documents.	TZA/TWN
		Organize capacity building in documentation and GCCE use for all staff who could use the system in their activities for querying and updating.	TZA/TWN
11	QMS with well developed and managed SOP's that are built upon previous versions that are developed collaboratively across the locations	Assign dedicated quality manager at each site to manage development, updates, audits, etc.	TWN/TZA
		Create internal auditing system across the two sites.	TWN/TZA
		Record non-conformities and use them to improve these processes.	TWN/TZA
		Assure all SOP comply with International Genebank Standards.	TWN/TZA
		Review all SOPs to ensure current activities are reflected in the appropriate building or work area, include the building layout, and reflect decision points to complement the workflow diagrams.	TWN/TZA
		All SOPs need to have detailed equipment registers including all maintenance and calibration schedules and suppliers of these services.	TWN/TZA
		Develop crop (or crop group) specific protocols for regeneration, viability testing, authentication, and other processes.	TWN/TZA
		In the Distribution SOP, develop a formal process to solicit feedback from seed recipients to improve processes and services.	TWN/TZA
12	Align minimum handling fees charged for genebank accessions with international standards	The seed handling fee should align with global practices and international agreements (ITPGRFA Article 12.3b).	TWN/TZA
		The policy for seed handling fees should clearly state which recipients are exempt.	TWN/TZA
13	Improvements in the transparency and allocation of funding of the routine operational budget	A dedicated routine operations budget should be allocated separately from any flagship, reflecting the central role of the genebank.	TWN/TZA
		Carry out impact studies on use to build evidence and stories for long term support.	TWN/TZA
		Develop a longer term plan for essential equipment replacement and upgrading for the genebanks at both sites.	TWN/TZA
14	Improved compliance with international agreements in relation to legal status of all accessions for conservation and distribution	De-accession material from the collection if the legal status does not allow distribution under SMTA	TWN/TZA
		No distribution of accessions without clear legal status to internal and external users.	TWN/TZA
15	Enhance the rational allocation of human resources for the long term	Allocate a location manager at each site with a focus on attaining a steady state and maintaining routine operations for the longer term.	TWN/TZA
		For essential positions, build in redundancies with 'deputies' that are trained to take on the task.	TWN/TZA
		Develop a staff succession plan.	TWN/TZA
		In the TZA genebank, recruit an additional position to allow for a clear reallocation of tasks for the three areas of operations (information/QMS, seed handling, and regeneration/ characterization).	TZA
		In the TWN genebank, separate the allocation of tasks for information system/QMS and managing conservation into two positions. The information system position could also focus on both sites as discussed in the LTG Business Plan but there would still	TWN

ID	Recommendations	Proposed priority activities to address recommendations	Location
		need to be a dedicated staff in TZA initially to fully implement and populate GCCE.	
		Continue to invest in staff capacity building with pairing staff from Taiwan/Tanzania or from different groups outside the genebank.	TWN/TZA
16	Improve the LTG Business Plan to secure the WorldVeg genebanks for the long term	The table on performance targets be updated and the targets be carefully reconsidered in each year.	
		Both genebanks develop a plan to upgrade their processes and to address backlogs as part of the Business Plan.	
		The activities planned for the next five years need to be put in a workplan with milestones that can be monitored.	
		The LTG Business Plan would also be helped with the addition of a section that proposes a longer term future focus for the collections in terms of the next generation genebank.	

Table 2. Updates since the last review of TZAGB

Status: 3=fully or mostly addressed, 2=partly addressed, 1=not addressed; 0=dropped/not applicable

ID	Previous Recommendations	Status	Comments
1	An important collection and one that is widely distributed in Africa and feeds directly into food security and nutritional quality in the region (Africa)	3	The reviewers agree with this statement that is also acknowledged in the LTG business plan and the WorldVeg operation plan
2	The new appointed genebank leader (N'Danikou) made an energetic and engaged impression and recognized that the review is an opportunity to guide him in his work planning and prioritising the work at the center. N'Danikou will probably require more training in some aspects, especially in analysis of larger datasets of characterization data.	2	The present review also agrees with this statement and was particularly impressed with the leadership and vision that the genebank manager has for the genebank. He would benefit from additional training on leadership and management skills.
3	The staff from WorldVeg-HQ in Taiwan are very supportive of the Regional center and its role, and there seems to be a close link between the two centers	2	The link between the two genebanks could be improved with more joint training and opportunities for working together
4	Seed processing looks highly professional, seed was cleaned manually, and this seemed to work well; drying facility for germplasm were good (10°C, 30% RH; after 3 weeks seeds were down to 6-7%)	2	The present review considers that the staff would benefit from further hands-on training on seed processing, as most of the steps are not compliant with international standards.
5	Field plots looked excellent, very well weeded, irrigated, individual accessions were isolated to some degree by other species being used as buffers, and isolation tents were in use for species that were known to have a high degree of outcrossing	2	The present review considers that standards for regeneration need improvement, especially for cross pollinated species and the processes can be made more efficient. Acquiring more net cages is necessary to deal with the regeneration backlogs.
6	There are key questions about the role of the center: As the holder of the African germplasm (~2000 accessions of African vegetables), this should be held here as the regional custodian for this important set of species. This ought to be in LTS, probably in 2 or at most 3 deep freezers. That material would not normally be distributed. Under this scenario clean seed would be distributed of elite lines, or breeders' lines (from established core sets).	2	The genebank is establishing an LTS genebanks and all its collections will be moved to the new facility shortly. It will be managed as a regular public genebank with the SOPs associated.
6b	An alternative approach would be to become a seed distribution center for elite lines only to farmers, private sector breeders and institutes (not crossing a sub-regional border), and let the	1	The upgrade of the Tanzania seed repository to a genebank with long term curation responsibilities for regionally important genetic resources is a model that

ID	Previous Recommendations	Status	Comments
	non-elite germplasm and material that is not in the core set(s) of each species be distributed from WorldVeg-HQ. The main disadvantage of this option is optics – African material collected or assembled by WorldVeg no longer held in the safe conditions of LTS within Africa		well fits the needs of Africa but also addresses considerable constraint to the import/export of seed for HQ in Taiwan.
7	Prioritization: The best represented species have about 100-300 accessions, but after the top 10 species there is a long tail with just a few, or even just one, accession per species. The reviewers believe that WorldVeg needs to focus on the most important African vegetable species (not necessarily those with the highest number of accessions) and recommend that they select the top 10 species, develop core collections of these, and have the core members available (sufficient seed, viability- and health-tested according to FAO standards)	1	The present review agrees with the recommendation, which is also acknowledged by World Veg management. However, the genebank continues to maintain a long list of species. They will need to prioritize use and decide which of the less important crops ought to be kept in an archived collection in the new LTS facility. In the future the status of the archived accession could be reconsidered and transferred to another genebank (as discussed in the LTG Business Plan)
8	To develop core collections will require prioritizing characterization and analysis of existing and new morpho-agronomic, potentially also molecular characterization data, and that these data be mapped to better understand patterns of diversity in order to support selecting the core accessions	1	Agreed and this does seem to be ongoing by the flagship and the genebank
9	WorldVeg-Arusha has a narrow geographical focus in East Africa (Tanzania, Uganda and Kenya feature most prominently), and the genebank and their work on diversity needs to be available more widely. This will require N'Danikou having an additional role of engaging with national agencies, NGOs and others across the subregions so that potential partners and users understand the role of the genebank and potential benefits of collaboration	3	Agreed. The head of the genebank is engaging with partners across Africa and seems to be doing a good job at this
10	Health testing: In the absence of a health lab and the skills required for operating such a lab, WorldVeg should explore the opportunity to bring the Nelson Mandela African Institution of Science and Technology (almost next door in Arusha), or IITA with their labs in Dar es Salaam, or even the Tropical Pesticides Research Institute (TPRI) in Arusha to see whether any of them can provide suitable tests as a service	2	Agreed. This is already happening with TPRI.
11	The center has to have a respectable database ASAP. The current situation of various unlinked spreadsheets is not workable, despite N'Danikou being able to track around it if he has the time, but even the most basic enquiry is laborious. WorldVeg-HQ is considering a swing to GRIN-Global, but not sure of the urgency of implementing that decision	2	Agreed. The shift to GGCE is happening and staff have received some initial training in its application. There is a gradual shift to the new system from 2023. But information is still scattered across different spreadsheets. and the old database A dedicated information officer is required to migrate all information into GGCE efficiently and effectively to improve use of GGCE for genebank management.
12	Storing conditions of MTS have to be improved. Temperature is ok, but RH has to be reduced even if it is at the recorded 45% (recorded on an old clock-faced hygrometer, which the reviewers doubt is reliable enough).	1	Agreed. The revision of MTS conditions to 4-5C and 15%RH is an urgent action that is required to reduce the deterioration of the seed quality that is being accelerated by the current conditions.

ID	Previous Recommendations	Status	Comments
	Alternatively, they could establish a drying room close by and convert to air-tight containers or vacuum-sealed packets. Temperature and RH need to be logged continuously. A servicing schedule for technical equipment also needs to be established		
13	A (better) viability testing strategy has to be developed. At the moment there is none – seed is tested when projects do it, or when seed kits are being distributed. The center should be aiming for good seed going into the store, being well stored, and viability being tested again at an appropriate time. NB: some of these seeds might not be orthodox, or might be orthodox with low storage potential (i.e. intermediate). There is also opportunity to research into storability and longevity of such seed	1	Agreed. The situation with viability testing remains critical and represents a significant backlog. The information on viability is critical for management to make good decisions about accessions and to ensure the quality of seeds distributed.
14	Health and safety: The center needs to invest in a better system of storage and shelving. At the moment, tall shelving and boxes that must weigh >30 kg stored at the top of the shelving, especially, is a real human health and safety issue. While the lower boxes are heavy and potentially problematic, bringing down the higher boxes from a ladder or from steps is an accident waiting to happen	1	Agree. The reviewers hope this will be resolved in the establishment of a new genebank.
15	In addition to the separation of roles between seed kit supplier and genebank, it would be advantageous to also split the seed room functionality so that genebank material is held systematically in one area, and the kits and larger lots associated with making up kits are held in a separate area of the seed store. Genebank material, if high-quality is stored under excellent conditions, does not need to be held in kilograms as is currently often the case	1	The present review agrees with this recommendation and suggest that the current MTS facility be used for the storage of larger packets for seed kit for distribution and that all genebank materials be moved to the LTS genebank under construction.

2 Assessment of genebank activities to sustain essential operations.

2.1 Availability of Germplasm

2.1.1 Monitoring of genetic integrity in Taiwan

TWNGB has a long history and currently holds about 61,838 accessions covering 166 crops and 330 species. An analysis of the data on the composition of the genebank shows that out of the 166 crops only 39 crops (23.5%) have more than 100 accessions, while 44 crops have only 1 accession. The top 10 crops include soybean, mung bean, tomato, pepper, eggplant, adzuki bean, okra, pumpkin, and other vegetables. These crops have more than 1000 accessions. While they make up only 6% of the collection in terms of number of crops, they represent 89% of the collection in terms of numbers of accessions. The Acquisition Policy (January 2020) also recognizes that 90% of the collection belongs to 20 crop complexes from 16 genera and 10% covers accession from 166 genera. These few accessions are mainly traditional vegetables that are not actively being researched/bred and are not well represented in other genebanks.

According to the LTG Business Plan, the curated collection is to be reduced to 60,000 accessions or fewer with at least 5,000 accessions archived based upon priority for use, duplication in other genebanks, and legal status. The annual target is to archive 1750 accessions with a long term plan to send these accessions to other genebanks for active curation. TWNGB does not have a clear plan for this rationalization, but it does have a list of crops prioritized for acquisition in Table 1 in the Acquisition

Policy. Species are listed and stared for criteria such as key collection of a global crop, active breeding program at WorldVeg, traditional vegetable that is a priority for Africa, traditional vegetable that is a priority for Asia, or an Annex I crop. The number of accessions conserved is given for each species and any future actions indicated, such as focus on the wild relatives, expand collection, develop core collection, and collaborate, archive, or donate to another genebank. In this table, there are only 18 accessions that are identified to be archived and 237 accessions to be donated. It was not clear what collaboration with another genebank meant but the focus was only on four species: *Cucumis sativa*, *Allium sepa*, *Raphanus sativa*, and *Phaseolus* spp. Thus, it was not clear in the Acquisition Policy how the genebank will determine any additional accessions to archive or donate for the future.

The reviewers did a preliminary assessment of the passport information available on Genesys and found that a very high proportion of accessions has been obtained from other genebanks. For example, 28% of the collection have PI numbers coming from USDA alone and thus are not unique accessions. According to the LTG Business Plan, a portion of the collection conserved in Tanzania is also conserved in Taiwan but the accessions cannot be directly linked so the degree of redundancies are not known. The reviewers anticipate that the rationalization could reduce the collection size by at least 25% or more if the legal status, availability of documentation, and seed viability are included in the criteria for archiving. This would allow for increased opportunities to address backlogs, efficiencies, and expansion to fill gaps in vegetable genetic resources in Asia as well as other areas globally. **The review team agrees with the need for rationalization and recommends:**

- **TWNGB should do a thorough assessment of the duplication of its accession in other genebanks utilizing the passport data they have.**
- **TWNGB follow-up with USDA and other genebanks to clarify the status of the accessions that they are currently holding in common.**
- **TWNGB should utilize this knowledge of the status of the conservation and availability of the accession in other genebanks to initially reduce the priority for viability testing and regeneration or archive the accession.**
- **TWNGB should utilize other criteria, such as priority crop for WorldVeg research programs, seed viability, legal status, or availability of passport information to further identify accessions that have a low priority for the backlogs or could be archived.**

In the self-assessment the genebank also reports that most of the collection are composed of cultivars or released varieties and only a minor proportion are landraces. However, it has been clarified during the review that the cultivars are taken as being traditional or local cultivars (not bred by breeders) and should be classified under the category as Land races. **The reviewers recommend that the passport data for these accessions be updated to correct the biological status classification and better reflect the unique nature of most of the accessions conserved.**

From acquisitions that were done in the past but not fully incorporated into the collection according to the 2019 Acquisition SOP process, the reviewers understand that a decision was made to accept these into the collection and give them accession numbers before viability testing are done and legal status is verified. These newly acquired accessions are conserved in a separate MTS room and are monitored separately in red on the summary of operations highlighted in the entrance to the conservation work area. These accessions make up the 'Red List' and have been given a priority for viability testing and regeneration since they are considered at high risk for loss. While the reviewers might agree with the need to prioritize these new accessions, the lack of baseline and monitoring of viability of the rest of the collection is also a risk to the genetic integrity of the older collection in long term conservation. Given the age of the collection and the lack of any baseline viability data, it can be anticipated that many of these accessions are losing viability and need regeneration. There is no clear evidence that the red list accessions should be a priority. **Thus, the reviewers recommend:**

- **Urgently, all accessions on the red list should be packaged and conserved under LTS conditions to prevent any further deterioration of the seeds.**
- **The red list needs to be rationalized taking into account critical available information (e.g. duplication in other genebank, legacy data attached to accession etc.) to determine their priority for regeneration as for any other accessions in the LTS.**

- **For the future, temporary accessions number should be given to newly acquired material, as described the previous Acquisition SOP (2019), until the genebank ensures that accessions enter the collection after meeting the criteria for quality and have sufficient seed number.**

The genebank staff is commended on their diligence in the proper labeling and organization of their workflow to ensure that accessions can easily be tracked along the genebank operations. Seeds are properly labelled along all stages of genebank operations (from harvest (and collection) to seed cleaning, drying, germination tests, packaging, and storage. Labels include the accession number (VI), the crops or species name, year of regeneration if materials have been regenerated. Generally, labels are included both inside and outside the collection or drying bags. After drying, accessories are packed in Aluminum foil bags and one label is placed inside and one on the foil bag. Accessions are neatly stored in the plastic racks in storage rooms and can be located easily in the storage room. Currently, it is not clear if all accessions have been barcoded. In the LTG Business Plan Table 1.3.1, WorldVeg committed to use QR codes for inventory management, seed viability monitoring, and seed distribution. The genebank also committed to use GCCE for oversight and management, to manage user request and distribution, inventory management and collection curation. This would indicate a commitment to fully using QR codes for labeling and for managing the risk of loss of genetic identity during routine operations. So while the reviewers recognize the progress made in labeling, **the reviewers recommend the full implementation of QR codes to enhance monitoring and management of data and operations through the GCCE management system.** This is recognized as a task for the Information Specialist in Taiwan.

2.1.2 Monitoring of genetic integrity in Tanzania

The current composition of the Tanzania genebank (TZAGB) stems direct from the times when the genebank was merely a seed repository and thus the original accessions seem to be a rather random set of material stemming from breeding and research programs. Only recently the composition has started to be focused based on joint collecting mission with National Genebanks in the region. The LTG Business Plan indicated that collection is expected to increase to 15,000 accessions by 2025 and increase by 3500 accessions annually until 2027 due to collecting activities funded by existing projects in collaboration with national genebanks in Tanzania, Eswatini, Benin, Madagascar, Ghana, and others. This is more than tripling of the number of accessions for routine operations of conservation in a genebank that has significant backlogs in many routine operations.

TZAGB lacks a process for acquisition between receiving new material and the decision to include it in the collection. This will result in the composition expanding without clear documentation and an assessment of the legal status, value of the accession or the quality of the seed to be conserved. The current collection in TZAGB contains non-African crops that according to the mandate should not be in the collection for the longer term, and material that is also maintained in the WorldVeg Taiwan genebank so could be considered redundant. TZAGB holds a collection of 5623 accessions belonging to 77 crop species, out of which 16 crops (20.7%) are represented by more than 100 accessions. These crops constitute 88% of the total number of accessions. Further there are 45 crops that have less than 10 accessions, half of which (27 crops) have only 1 accession. The top 10 crops in Tanzania genebank include okra (by far the greatest number of accessions), amaranth, African eggplant, tomato, cowpea, roselle, pumpkin, jute mallow, African nightshade, and sweet pepper. These make up 74.7% of the total number of accessions in the collection. The composition of the Tanzania genebank follows the same pattern as in the Taiwan genebank, with a few crops with majority of the accessions and a long tail of crops with few accessions. **As in TWNGB, the reviewers recommend that TZAGB prioritize which crops and accessions to include in the collection for the long term and archive those accessions currently considered of low priority.** The prioritization should include an assessment for duplication in Taiwan or other genebanks. It should utilize the process for verifying the status of conservation of the duplicate accession in the other genebank and other criteria to identify accessions for archiving that is described for TWNGB. This process is timely given the new LTS facilities that are being built.

The tracking of the accessions in the genebank is satisfactory as all accessions are well labeled, with a label inside and outside the seed bag. Currently the seed bags are labeled with the crop name, accession name, seed amount in grams and date of harvest. A few of the seed bags also have barcodes. The use of "accession name" in tracking accessions is not helpful as they do not follow a logical sequential order

and are very variable. It is also possible that different crop accessions could have the same name, which can make tracking of location of stored germplasm very complicated. During the review, the localization of three accessions in the MTS were checked, and the staff had difficulties in finding the accessions, but ultimately found them. It is thus important that seed bags are properly labeled. In the baseline, the TNZ genebank indicated that they had a QR printer and scanner (purchased in 2022) but the reviewers saw no evidence that the barcode was being used routinely for relabeling. **The reviewers recommend that the label used for each package for an accession in the MTS contain the unique identifier of the accession, which is the Accession Number, and a barcode or QR code.** The genebank could consider using other information on the label such as Crop Name, Batch Number (in case there are several regeneration batches) and date of harvest, that could be added if they have not fully utilized the QR code yet in the labels.

The reviewers believe that there is a need for urgent action to reduce the risk of loss of genetic integrity of accessions currently being conserved in the medium term facility in the TZAGB. All the accessions are being maintained under MTS condition at +10C° and 30%RH. Under these conditions the seeds would be aging at a fast rate and reach the threshold for regeneration quickly. There is evidence (based on viability tests documented) that the seeds viability is generally low and declining. The impact of this situation is that the seeds will be of poor quality and would increase the regeneration backlog of the genebank. Further, as most of these seeds are also destined for distribution, including as part of the seed kits, the genebank would be distributing poor quality seeds which would also hurt the reputation of WorldVeg. Thus, there is an urgent need to secure the MTS collection, irrespective of the seed viability status. The aim of the recommended actions is to stop the further deterioration of the seeds in the MTS. **The reviewers recommend that following actions be taken urgently:**

- **The storage condition of the current MTS facility should be revised, and the temperature should be reduced to 4-5C and RH to 15% to ensure that the seeds are kept in a dry and safe environment. This measure will also provide a better storage condition for seed kits.**
- **All essential documentation (passport and management data) of all the accessions should be compiled in a consolidated file (Excel file) to allow prioritization of accessions for viability testing, shift to LTS, and/or regeneration.**
- **Based on the essential documentation, set priority of crops and accessions within crops, and identify obvious duplication, both within the collection in Tanzania and Taiwan as well as other external genebanks**
- **For each priority accession, check the seed MC to ensure that it is within the acceptable range for the crop (3-7% seed MC). If not, the whole accession/batch must be dried without delay to the accepted standard. If an accession contains different batches, keep them separate and you may only need to test seed MC for 1 or 2 batches.**
- **Repack the dried seeds for each batch of an accession in two aluminum foil bags and seal them hermetically. Label each bag with the 'Accession Number' and 'Batch Number' and possibly the crop name.**
- **Put one foil bag into a box to send either to the Taiwan genebank or another international genebank in the region, such as ILRI in Ethiopia or ICRAF in Kenya or even IITA in Nigeria, as a temporary black box safety duplication and the other kept in TZAGB MTS facility, until the LTS facility is fully operational.**

2.1.3 Monitoring of viability in Taiwan

It should be stressed that the reputation of a world class genebank lies on its ability to maintain the genetic integrity of its accessions so that it can provide high quality seeds (meaning high viability seeds) with diverse traits that users of germplasm are looking for. It is evident from the baseline and on site review that the backlog on viability testing is an area of major concern. The reviewers observed that information on initial viability is lacking for many genebank accessions. It seems that historically initial viability testing (for new incoming seeds) was not carried out and this practice continues today. Since, 2020, accessions coming from regenerations are systematically tested for their viability; remaining capacity is used to monitor seed viability of conserved accessions. Consequently, very limited information about the quality of the seeds that are conserved in the genebank is available which makes decisions on regeneration and distribution difficult. Criteria used for regeneration is solely based on the quantity of seeds left and the age of the accessions. It is assumed that the older the accession, the more

likely for it to have low viability and needs to be regenerated. But this is not always true, as the viability also depends on the initial quality of the seed and genotypic differences between species and even accessions within species. Therefore, this practice poses a serious threat to the whole collection and needs to be remedied.

There is also a problem with the germination test protocols for some crops that often give low germination percentages. It is important that the reasons for such results are determined. They may be due to poor initial seed quality, dormancy of the seeds, germination conditions etc. WorldVeg deals with many crops and species for which precise germination protocols may not be available (especially the crop wild relative species). The research needed to develop improved protocols is a task for the Curator for Cucurbitaceae and Tomato but given the essential nature of these protocols for both genebanks and users, TWNGB might need additional resources and research partners. Thus, the reviewers support the activities ongoing, but this needs to be addressed as a priority research need.

Given the backlog and high priority for viability testing, the inadequate capacity for viability testing should be addressed urgently. According to Table 1.6.1 in the LTG the number of staff involved in seed processing, viability testing, and storage is six with the overall management as a task for the Information Specialist, one seed lab assistant, and four seed lab laborers. The baseline indicated that one seed lab laborer and 1 temporary laborer has a sole task focused on viability testing. At the site visit, the reviewers were told that currently there is only one research assistant carrying out germination tests and a maximum of 3000 tests can be done annually. The LTG Business Plan indicated that the target is to conduct 6000 viability tests per year but to meet that target they will have to significantly increase capacity., both in terms of human resources and physical facilities for viability testing At the site visit, it was observed that there was limited space for expanding the seed viability testing. To increase the capacity of viability testing, it will be necessary for World veg to reorganize and optimize the space of the seed viability testing area. The reviewers estimate that even at the doubling of the viability testing rate, it will take more than 10 years to address this backlog to maintain WorldVeg collection of 60,000 alive at a steady state management status. As discussed in the previous section, another strategy could be to rationalize the collection to a manageable level given the human and financial resources available. This could involve, for example, making some hard decisions to focus on a few priority crops (maybe 50 species) and those that are unique and of high value to WorldVeg partners. The rest of the collection that are not unique or less important are archived in a section of the LTS and are deregistered from the collection. This rationalization could be used to both improve the composition of the collection but also to prioritize accessions for viability testing. **Thus, the reviewers recommend**:

- **All legacy data on seed viability of the accessions should be collated and included in the GGCE database to improve the baseline information for management decisions.**
- **Precise protocols for viability testing and monitoring frequency for each of the crops/species that are handled by the genebank should be developed and included in the Conservation SOP**.
- **Increase capacity to test 6000 accessions annually per year (as planned) with improved seed viability testing facilities/space and more staff.**
- **Prepare a roadmap and longer term plan to address the backlog of viability testing to facilitate decisions on distribution and regenerations.**
- **For the longer term, test all newly acquired and/or regenerated accessions to give a baseline and establish monitoring of viability on a routine basis using crop species specific protocol.**

2.1.4 Monitoring of viability in Tanzania

According to Annex 2, only 36% of the accessions have been tested for seed viability and only 21% of those tested had viability above 85%. TZAGB has a significant backlog of seed viability testing that needs to be managed and given priority by the genebank**.** It seems that routinely seed viability tests are carried out on seed receipt (new materials), after regeneration and before distribution. TZAGB also has an issue with either poor seed quality or inadequate viability testing protocols. The results of the viability tests, as evidenced by the genebank records, show that a significant number of accessions have low viability, even just after regeneration. This is a similar finding to the Taiwan genebank and the reasons

for these poor viability results need to be investigated. If needed, crop specific protocols for viability testing need to be developed and used.

Currently, the LTG Business Plan, the annual target for germination testing is 1000 accessions but the current rate is 875 accessions per year. Given the current number of accessions, the backlog will take 4 years to address the need for baseline viability test but that does not include the need to also do monitoring of accession in the MTS. When the expected increase in the number of accessions to 15,000, the number of years to address the backlog in baseline viabilities will increase to more than 13 years. Thus, the TZAGB needs to consider doubling or tripling the number of viability tests annually as well as to modify protocols for specific crops. Currently, the staff allocated for seed processing, viability testing and storage includes one research associate seed specialist, who also has responsibility for tasks related to inventory management, seed testing, distribution, and information management. There is also one seed attendant and from 2-6 seed laborers with a focus on seed processing, seed viability testing, and seed storage. Thus, there could be a need to consider an allocation of staff dedicated to seed viability testing, especially given the planned expansion of the collection.

In Tanzania, germination tests are carried out in a petri dish in the germination cabinet. For some species (e.g., amaranth, jute mallow), germination tests are also performed in soil in screen houses, where they were found to have better results than in petri dishes. It should be noted that the germination cabinet in place has no light control and thus germination tests are carried out in the dark. This may not be appropriate for most species, requiring a light/dark lighting regime for germination.

Overall, the reviewers recommend:

- **Acquisition of two functional germination cabinets with light and temperature control for viability testing.**
- **Allocate staff fully to germination/viability test, provide hand-on training by staff in TWN or other experts who could also advise/verify if methodologies used are appropriate or if there is need for doing research on improved protocols.**
- **Develop and utilize crop specific seed viability testing protocols that are clearly described in the Conservation SOP.**

2.1.5 Monitoring of germplasm health in Taiwan

The issue of germplasm health is taken very seriously in Taiwan and the import and export of germplasm materials from the genebank follow strictly the quarantine procedures in compliance to Taiwanese Plant Protection and Quarantine Act for the issue of phytosanitary certificates. The genebank has developed clear SOPs and instructions sheets to guide its staff on procedures to follow to the import and export of germplasm materials. TWNGB have a dedicated staff [Mary] who is the focal point for liaising with the national phytosanitary authority – BAPHIQ, with whom they work very closely. A dedicated bench space to handle all the quarantine materials is also provided, which is visited regularly [weekly] by BAPHIQ phytosanitary officer to check compliance. The Acquisition policy describes a process required for new acquisitions that are sent from countries that do not have pest risk assessments, so importation is done under quarantine. Given the known or unknown risk of the introduction of the wild relatives and diseases, virus, insect pest and other biotic threats, there is seed of several recent introductions kept in separate quarantine storage room in the genebank, to comply to these national quarantine procedures. The seeds are kept in separate cold room at -18C. The seeds can be regenerated in Post-Entry Quarantine to compliment the regeneration being done in TZAGB. If the new acquisition is lost in Tanzania or if needed for use outside Taiwan, the Taiwanese Plant Protection and Quarantine Act will not allow for TWNGB to distribute samples of the original seeds from the introductions conserved in the quarantine storage room to requesters outside Taiwan even if the requester is allowed to import.

WorldVeg has a dedicated Plant Quarantine Laboratory (PQL) to conduct standard tests on Solanaceae for viruses and viroid. A separate SOP has been developed by PQL but was not shared with the reviewers. The reviewers understood that in the future, PQL will work on developing standard testing protocols for cucurbits. Insect pests in leguminous crops are managed mainly through visual seed cleaning. For other crops, the testing depends upon the requirement for the NPPO regulation for the recipient country. PQL has excellent facilities and is certified by the BAPHIQ (issuance of certificate valid for 4 years). WorldVeg has constructed new buildings and PQL will move to new premises with

more workspace than it has now. For Solanaceae, the accessions are conserved in isolation (based upon positive or negative test result) and tested every 4 years. Each germplasm health test requires 400 seeds per accession and costs 40 USD. This is a burden for the genebank and mechanisms for reducing this sample size are needed and the need to carry out germplasm health on materials that have been conserved under sterile controlled conditions should be reevaluated and negotiated with BAPHIQ.

Germplasm health testing also seems to be done as part of a few of the routine operations. The LTG Business Plan sets annual targets for germplasm health testing and disease cleaning in Table 2.1.1 including health testing before distribution (500), health testing before regeneration (1000), disease cleaning before regenerations (2500), and disease cleaning before distribution. The comments would indicate that disease cleaning would just be seed cleaning by hand. It is not clear why the testing occurs so frequently for the same seedlot but the estimated cost for this health testing is 60000 USD annually and this would not include any additional cost for testing for import/export unless the health testing for distribution is just for accessions to be exported. While efforts have been made to streamline and clarify the health testing needs, there are still opportunities to make further improvements. One opportunity is highlighted in the LTG Business Plan to add seed testing data to GGCE to keep track of seed health and quarantine certificates.

The reviewers recommend:

- **Crop Trust should encourage the involvement of WorldVeg in the Germplasm Health Community of Practice of the CGIAR Genebanks Initiative**
- **Reconsider technical aspects of seed health testing such as**
    - **Reduce sample size needed for testing of germplasm health,**
    - **Increase length of time for the validity of seed health certificate**
    - **Test the use of bulking instead of individual accessions to reduce seed requirement for each test.**
- **Establish a process to allow for reexport of the original seed of introductions that are conserved in the quarantine storage and are currently excluded for entry into Taiwan.**

2.1.6 Monitoring of germplasm health in Tanzania

The genebank does not have any germplasm health testing facilities and relies on the services of the National Plant Quarantine and Phytosanitary Service (NPQPS) of Tanzania for any germplasm health issues in the genebank. The NPQPS visits the genebank at least twice a year and are also the authority for the issue of the Phytosanitary certificates for the export of plant germplasm from Tanzania. The genebank staff follows the post quarantine regulations and procedures and have developed instruction sheets that allow staff to follow the appropriate steps.

The genebank wished to enhance its seed health capabilities in setting up a seed health lab with trained staff. However, the review considers that, while this would be desirable, the system in place is working well now for the size of its collection and is not a high priority. Utilizing the technical expertise in Taiwan would also be an additional step they could take to enhance the seed health capabilities in TZAGB.

2.1.7 Ensuring sufficient stocks of germplasm in Taiwan

The reviewers were able to visit the fields, greenhouses, screened cages, and post-harvest handling facilities. All these facilities are well managed, including irrigation and pest management. Pesticides are sprayed on the fields using drones, an activity that is outsourced. The total capacity for regeneration is limited and might need to be expanded – this depends on the final number of accessions and their requirements. The use of facilities outside the WorldVeg fields, for crops and genotypes less adapted to the local environment, might need to be considered. Currently only the facilities in WorldVeg Tanzania are used. Furthermore, the lowland Taiwan facilities, already having difficulty with drainage, might become less useful given the climate changing; alternative regeneration sites might also be required. As soon as the composition of the collection in the steady state is clearer, a calculation of the required capacity should be made, considering the number of accessions and the specific requirements of the different crops in terms of space, isolation, pollination, etc. This is not yet possible as the composition of the current collection might change considerably after rationalization.

The identification of the regeneration plots is done with handwritten labels that stay with the seeds after harvest and during the first pre-drying and threshing. Verification prior to harvest is done by checking the harvest bag label with the field plot label. The use of computer printed labels, possibly using barcodes, should be considered. Another issue is that different curators use different methods for keeping track of accessions on the regeneration plots. Labels in the field are only labeled with "accession number." No bar codes are used, and records are made on paper sheets. Accessions in the field are tracked using regeneration maps. Although TWNGB considers the most efficient process to capture data from the field, greenhouse, or cage is to record on paper, **the reviewers recommend that TWNGB transition to the use of tablets and expand the use of barcodes in the regeneration fields for verification and tracking of accessions during regeneration/multiplication, characterization, harvesting, and post-harvest handling.**

The post-harvest seed processing activities for wet seeds (Solanaceae crops) and dry (legumes) seeds are done in separate work areas. For the dry seeds, seed extraction is carried out on the roof of the genebank building. The access to the roof is through a narrow passage and staff must carry bags of the harvested seeds upstairs to reach the roof. **The reviewers recommend that access to the roof drying area be improved by installing a lift to move the seeds materials to the roof more efficiently.** Seeds are extracted manually and there is no seed cleaning equipment, like threshers, blowers etc. Seeds are placed in wire mesh bags with labels inside the bags and placed on benches that are well aerated. The reviewers suggest that the efficiency of the seed threshing/cleaning process could be improved with the addition of a small thresher and seed blowers.

The wet seeds are extracted by hand or ground in a wet seed processing area and placed in buckets for fermenting to facilitate the seed extraction. The workspace inside the wet seed processing laboratory is not adequate to allow for the efficient operations required to ensure the timely processing of many samples harvested from the regenerations at the same time. For some of the crops, seeds are then separated from the debris, washed, and pre-dried in the inside area. For other crops, the seeds are further processed in a very limited open area outside the processing laboratory where there is a small, concrete work platform just outside the door and a small open area between the building and the road with a tree on one side. The wastewater after fermentation is disposed of in the open area and the seeds are dried initially in the sun or the shade of the tree before transferring to a drying cabinet for further pre-drying under controlled conditions (15C and 30-34% RH). The workspace outside for washing, fermentation, seed extraction, elimination of wastewater and drying in sun/shaded areas is very limited and undeveloped for efficient seed processing. Generally, the workspace allocated for the processing of crops with wet seeds is inadequate. **The reviewers recommend that the efficiency of the post-harvest handling process be improved by upgrading the wet seed extraction facilities with more workspace inside the processing laboratory as well as the workspace outside with a large, concrete work area, outside sinks and countertop workspace, better system to eliminate wastewater, and dedicated covered areas for the drying.**

One of the main issues for routine operations is the significant backlog TWNGB has in regenerations. This has obviously been recognized by the genebank given the two projects they have ongoing to address this backlog. Unfortunately, the extent of the backlog is still not really known given the backlog in the viability testing. Based on the information given in the baseline and summarized in Annex 2, about 25% of the seed accessions need regeneration due to inadequate seed number and more than 50% of the accessions could need to be regenerated based upon poor seed viability. This could be at least 33,000 accessions or more and given the annual number of accession that they anticipate regenerating (given in Table 2.1.1 in the LTG Business Plan), it will take about 12 years to address this backlog, assuming that there is no increase in the collection or in the numbers that require regeneration. The reviewers have discussed the need to rationalize the collection for archiving but also prioritizing accessions in this regeneration backlog.

Part of the regenerations are done by collaborating companies, in kind, however in some cases the quality of the produced seed is not sufficient. TWNGB utilizes a separate information system to monitor regeneration by the partners and to solve problems early if needed. The partners obtain annual training and there is a follow-up workshop to discuss the outcomes of the season's regeneration. This process of monitoring, feedback, and improvement should result in the development of regeneration partners that produce the required quantity and quality of seed required for long term conservation. The partnerships

have been established to deal with regeneration backlogs through the Taiwan Asian Vegetable Initiative and the Taiwan Council of Agriculture germplasm regeneration project. **The reviewers recommend to monitor longer term performance of each regeneration partner to deliver a consistent supply of high quality seed to reduce the risk of loss of genetic integrity of the accessions.**

2.1.8 Field collection of garlic

TWNGB maintains a field collection of about 200 garlic accessions, which is considered an important and unique collection for the region. (source: TWNGB staff) Pathak (1997) [1] described the importance of *Allium* crops to Asia where it is crop that is only second in regional and international importance to tomato. It is widely grown and consumed but its productivity is very low. When this report was published, AVRDC (WorldVeg) had recently added *Allium* crops to its mandate by developing collaboration with national efforts to facilitate the flow of material and technologies across the region. Pathak (1997) described "At AVRDC, major emphasis is given on the improvement of productivity in onion, garlic and shallot crops for the tropical environments, with active cooperation from several international research institutes, regional centers and National Agricultural Research System (NARS) partners engaged in the improvement of these crops. Special attention is being paid to build a large germplasm base for these crops. Developing lines with higher levels of resistance to major prevalent diseases (viz purple blotch, Stemphylium blight and basal rot) and insect pests (thrips), besides, developing tolerance to abiotic stresses like high temperature and moisture stress (high and low) are given major emphasis viruses are the most serious problem in garlic and shallot crops. Thus, virus elimination and indexing has been given priority in these crops."

The small collection of garlic could be a result of this expansion of the crop mandate of WorldVeg but it seems that *Allium* crops are no longer seen as part of the crop focus. This has left the small garlic collection without a user base in WorldVeg and insecure for its long term conservation. It seems this vegetable crop and its diversity in farmers' fields or gardens is important to the region and internationally. It is a crop where the exchange of genetic diversity is still not easy, both from policy and phytosanitary constraints. Thus, maintaining and distributing this small collection, whether in the field or in vitro, is not currently cost effective but one option for WorldVeg is to once again expand its focus for garlic or other *Allium* crops. The increased number of accessions and the increase in the use could justify the investment into securing long term conservation of these crops.

The reviewers understand that there has been attempts to develop partnerships with other *Allium* collection holders in Europe. The Acquisition Policy indicates that the garlic accessions would be donated to RDA but the reviewers understood that this was not possible. These partnerships might lead to safety duplication of the collection or a transfer of the small collection to that institute and is clearly also an option to manage the long term conservation.

Currently, to conserve the accessions for the long term, the accessions are planted and harvested each year to conserve them. These accessions do not flower in the regeneration site, and the cloves are collected for propagation. This yearly renewal of the accession has resulted in the build-up of disease in the accessions. This is not only a risk for the long term conservation but, together with phytosanitary issues, limits distribution of the accessions outside Taiwan. The management is envisaging culturing the accessions and establishing an *in vitro* collection that will eventually be conserved in cryopreservation. This would increase the opportunities to produce disease-free material that can be safely distributed and establish a cost effective safety duplication. The genebank currently has access to a dedicated tissue culture laboratory that is not operating but equipped with two laminar flow cabinets, adequate space for an *in vitro* conservation facility, and has one staff member with the skills for *in vitro* work. This shift of the collection to in vitro could facilitate the access to and distribution of the garlic collection but could also require more dedicated technicians and significant resources that might not be efficient or cost effective for the small number of accessions in the collection and this investment would be a tradeoff with other needs of the genebank. It is important that WorldVeg consider the resources needed to conserve this small collection for the long term before establishing an in vitro and cryopreserved collection. **Considering all the issues, the reviewers recommend the implementation of one or two of these three options for securing the long term conservation of the garlic collection:**

[1] Pathak, C.S. (1997). *ALLIUM* crop situation in Asia. Acta Hortic. 433, 53-74 DOI: 10.17660/ActaHortic.1997.433. https://doi.org/10.17660/ActaHortic.1997.433.3

1 **Transfer or safety duplicate the *Allium* collection at another genebank, as being currently explored. No investment will be needed for in vitro conservation.**
2 **Investment into the cost effective development of the tissue culture facility to facilitate access and long term conservation with virus elimination and improved plant health.**
3 **Increase the cost effectiveness for field and in vitro conservation with the expansion of the collection to include more regional diversity of garlic or other *Allium* crops.**

2.1.9 Ensuring sufficient stocks of germplasm in Tanzania

TZAGB also has a backlog in regenerations currently that is contributing to a high risk in the risk register in relation to the lack of safety duplication. Annex 2 indicates that the number of accessions that need regeneration could be as much as 4500 accessions. The capacity in Arusha seems to be sufficient for eliminating the current backlog, and certainly for running the genebank in a steady state. The LTG Business Plan indicates that the annual number of accessions to be regenerated is 1000 so the backlog could be addressed in 5 years if the collection size did not expand. TZAGB plans to expand the collection to 15,000 or more in the next 5 years and the staff indicated that most of that will need to be regenerated given the low number of seed that the partners are sharing from the collection missions. Currently the regeneration capacity is shared with the genebank in Taiwan, such as new acquisitions from countries that still require pest risk assessment in Taiwan, and with other regeneration activities that are not directly related to reducing the backlog, such as characterization experiments. This will result in a delay in the elimination of the backlog.

TZAGB did not share a SOP for regeneration during the site visit, but the three old regeneration SOP shared from Taiwan will be an excellent guide for their routine operations for the specific crops. The reviewers have assumed that the Regeneration Policy would apply to both sites. During the site visits, the reviewers were not made aware of the examples of the engagement of the Taiwan staff in the capacity building or joint planning with the local staff in Tanzania. In finalizing this review report, the Head of the TWNGB clarified that since 2022, Taiwan staff have engaged actively with Tanzania staff, including yearly visits, capacity building in regeneration, introducing techniques like bagging and ring pollination, and sending equipment and materials from Taiwan to Tanzania for regeneration. Greater engagement of the staff in the two sites that have responsibility for regeneration would be beneficial to both staff. One key joint activity could be to adapt the 2019 version of the regeneration SOP to meet the crop specific protocol and processes for Tanzania**. The reviewers recommend greater engagement of staff responsible for regeneration in Taiwan and Tanzania to address the capacity building needs in Tanzania and to develop crop specific protocols in a regeneration SOP.**

The three regeneration SOP are also excellent guides for developing enhanced regeneration capacity for those crops that require mesh cages. Currently, the genebank only uses the facilities of WorldVeg in Arusha that consist of well irrigated and well-maintained fields and a limited number of mesh cages. The capacity of the cages is limited and as a result some material must be regenerated in the open field, whereas regeneration in the cages would be preferable. To avoid pollen contamination between accessions, for some crops that are necessarily grown in the field, the flowers are covered in paper bags that can reduce the success of pollination or the quality of the seeds. Therefore, the capacity of mesh cages should be increased, allowing more accessions to be regenerated in these cages. Obviously accessions of different crops can be regenerated jointly in these cages. **The reviewers recommend that the number and type of mesh cages be increased to allow for secure regeneration that maintains the genetic integrity and seed quality.**

Finally, it appears that it is very difficult to produce appropriate amounts of sufficient quality seeds for some accessions. This limited regeneration success could be explained by the climate conditions at Arusha so for some accessions regenerations in other climatic conditions would be preferable. Pursuing options for regenerating at other sites in Tanzania or outside Tanzania are therefore essential. The LTG Business Plan set a target to externally regenerate 2400 accessions annually with NARS partners. The reviewers agree that TZAGB could utilize external regeneration or multiplication as an opportunity to enhance the capacity of the national partners doing the collection to do regeneration at their sites before the seed is sent for conservation at TZAGB. This will require capacity building for the partners that would be beneficial to the long term conservation of the accession locally. It might also require additional resources be made available to the partners and careful monitoring, such as that being done by TWNGB in their partnerships with the private sector to address regeneration backlogs. **Thus, the**

reviewers recommend that TZAGB address the growing regeneration backlog from new national collections, utilizing the experience from TWNGB, to increase the capacity of the national collecting partners to regenerate/multiply and provide high quality seed with adequate seed quantity.

2.2 Security of the crop collection and the genebank

2.2.1 Safety and security of the crop collection in Taiwan

The genebank is giving high priority to safety duplication and has focused on meeting the performance target of 90%. They aim to reach 90% by 2025 and for all their accessions to be safety-duplicated in at least 2 locations by 2027. More than 70% of the collection of WorldVeg have been safety duplicated of which 99% have been safety duplicated in at least 2 locations (RDA, Korea and SGSV, Norway) in 2 continents, according to the self-assessment report. Of the 13,672 accessions of soybean, 11,395 accessions are safety-duplication in Korea, SGSV, Norway as well as at USDA. The review agrees that good progress is being made and the performance target can be easily achievable. During the visit genebank staff were actively packing seeds for safety duplication.

2.2.2 Safety and security of the crop collection in Tanzania

One issue that should be addressed about safety duplication is the extent of duplication that exists between the WorldVeg collections in Tanzania and Taiwan. It is clear from the review that passport information is not complete so it will be more difficult to identify the source of accessions in both genebanks. TZAGB reports that there are 1607 accessions of amaranth, African eggplant, African nightshade, cowpea, Ethiopian mustard, jute mallow, lablab, lagos spinach, moringa, mungbean, okra, pumpkin, roselle and spider plant as actively safety duplicated in TWNGB, meaning that these accessions are incorporated into the TWNGB and actively managed independently of how the collection at Tanzania genebank are managed. If the accessions are integrated in the Taiwan genebank, it could constitute a safety duplication but more likely a redundancy. There is still some confusion about how many of the Tanzania accessions are safety-duplicated in Taiwan and how many are further duplicated in other genebanks (Korea, Svalbard). From TZAGB's perspective, it is preferable that they are safety-duplicated as a black-box system in at least two locations – Taiwan LTS and Svalbard, or in RDA by Taiwan-Korea agreement. It is important that TZAGB attain the target of more than 90% for safety duplication performance target. The reviewers have already recommended an exercise be carried out to identify duplication in TWNGB or other genebanks, including safety duplication by TWNGB. This will be of benefit to TZAGB in prioritizing accession for safety duplication.

2.2.2 Safety and security of the genebank facilities in Taiwan

The genebank facility at TWNGB was first designed and constructed in 1985 to house the vegetable germplasm collection. It was further renovated and expanded in the period 2009-2011 (Schreinemachers et al., 2014). The storage and drying facilities of the genebank is composed of 12 rooms – (LTG Business Plan, 2023, table 1.6.3)

1 Drying rooms (15.6 m2) maintained at -18°C 10%RH
2 Drying room (15.6 m2) maintained at -18°C 10%RH
3 Acquisition room (10.8 m2) and) maintained at +5° C and no RH control, seed in AL foil (used for LTS of original seed sources)
4 MTS (147 m2) maintained at +5° C and no RH control, seed in AL foil,
5 LTS (147 m2) at -18° C and no RH control
6 Short term room -for temporary storage maintained at 15°C and 15% RH (used for temporary storage of seed packs and seed lots for processing, shipment, and pre-storage)
7 Cold chamber for seed kits (11.5 m2) maintained at +5° C and no RH control, seed in AL foil;
8 Cold chamber for viroid -negative materials (13.1 m2) maintained at +5° C and no RH control, seed in AL foil
9 Cold chamber (31.8 m2) maintained at -20°C back up freezers (currently out of function because of all compressors- rooms need to be renovated – could be used for storage in freezers, for quarantine and distribution).
10 Cold chamber (16.5 m2) maintained at -20°C back up freezers (as per #9 above)

11 Quarantine room (11.5 m2) maintained at-20°C freezer inside. Storage of seed that cannot be grown out in Taiwan at -18 °C in freezers inside (RH not provided as all seed is stored in aluminum foils.
12 Walk-in cold room at 10°C (used for temporary storage of harvested fruits, before processing, wet-harvested crops such as Solanaceae crops.

Most of the storage rooms are in good conditions, but some need renovation. As discussed in the risk assessment, there is also need for revising the electric system in the genebank that is old and need to be upgraded to ensure safety of the genebank infrastructure. The genebank is fitted with a monitoring and emergency notification system that relay to cell phone of the genebank curator in case of emergency.

The overall aim of a seed genebank is to conserve genetic materials under the best storage conditions that prolong the seed longevity as long as possible and reduce the frequency of regeneration (to limit genetic erosion). The best condition that will achieve this objective is to keep all seeds in hermetic containers at -18±3°C and at an RH of 15±3%, i.e., under long term storage conditions, as per FAO international standards (2014). Seeds must be dried to 3-7% MC, depending on species. Many genebanks also keep seeds at MTS +4 to +10°C and RH of 15±3% for limited time mainly for distribution, but that should be avoided when possible. These correspond to FAO international standards (FAO, 2014).

The reviewers observed that the drying room facilities are excellent and operating well. The seeds are well spread out on trays and/or in open paper bags with very good aeration. The temperature and RH is within the limits of the international standards. However, the reviewers noticed that the RH on the dashboard was showing 23% RH (higher than the 10% RH target). It is critical that RH is well controlled but if the MC is within the range of 3-7% after a reasonable amount of time, it should be fine. The reviewers noted that determination of MC and quarantine work area are located at the entrance of the restricted area of the genebank, which do not have a trap door and the area is not RH controlled. This presents a great risk for the security of the genebank in terms of contamination risk for the handling of quarantine materials and for risk of moisture absorption of the seeds for MC determination process and seed packaging. When the dried materials leave the drying room, they must be transported in closed containers to prevent reabsorption of moisture. This is very important in the Taiwan genebank as there is a sharp gradient of RH in the drying room (10%) and outside ambient RH (60-70% if not more). **The reviewers recommend:**

- **The MC determination area and quarantine work area to be separated, and MC determination conducted in a more secure location close to the drying room and quarantine storage room.**
- **The area used to determine MC has RH controlled to 15%RH.**
- **To minimize any exposure of the dried seeds to high moisture outside the drying room, seeds are transported in a closed container (like plastic Tupperware with silica gel in them) from the dryer to the MC determination and the seed packaging area.**

Taiwan genebank has the luxury of having many storage rooms in good running conditions, where temperature is well controlled; so, storage space is not a limitation. However, RH in most storage rooms (except short term storage room (#6) are not controlled, which is not following international standards. The explanation for this is that the seeds are packed in hermetically sealed aluminum foil bags and thus it is not necessary to control RH. This is a risky assumption since there is often not the full guarantee that seed packets are entirely moisture proof, even when sealed. Further seeds are not vacuum sealed which is also sub-standard. Sealing under vacuum has two advantages, it allows one to determine if the seal is fully hermetic and it reduces the oxidative process of air inside the packets that impacts the seed aging process of the seeds and reduces seed longevity (Groot et al, 2014). If not sealed under vacuum, then it can be a good practice to include some self-indicating silica gel inside the packet, as an indicator if moisture has entered the seed packet. Thus, **the reviewers recommend that seed packs are vacuum sealed, and the security of the seal checked routinely.**

Currently the MTS is used for the conservation of small packs that are used for distribution, regeneration, viability testing and the remnant samples. MTS is at 5C with no control of RH so while the use of this temperature is more comfortable for the staff to operate in, it does not meet international standards. A more secure alternative (being used by other genebanks) is to eliminate the use of the MTS,

and transfer seed packets for distribution to standalone upright freezer at -18°C to allow easy access for genebank staff and move all seed packs for regeneration, viability testing and remnant samples to LTS conditions to prevent further seed deterioration. **To improve storage conditions for all seed packs, the reviewers recommend:**

- **Ensure all accession in MTS and in the new accession room are conserved in LTS conditions (if possible) and the relocation recorded in GGCE to ensure closer monitoring.**
- **Upright freezers should be acquired, and the cold rooms (#9 and 10) renovated and fitted with these freezers to be used to conserve distribution packs.**
- **Seed packets to be used for regeneration, viability testing and as remnant be conserved in the LTS.**
- **If the seed packets are not vacuum packed, the RH of the LTS storage rooms should be set to the international standards of 15±3%.**

2.2.3. Safety and security of the genebank facilities in Tanzania

The Tanzania genebank was established in 1992 as a WorldVeg seed repository for African vegetable crops. The collection is maintained in a cold room under Medium-Term Storage (MTS) condition at +10C° and 30% RH [internal logger read 45%]. Long-Term Storage (LTS) cold room (-20°C and 15% RH) and other new genebank facilities (drying room, seed lab, seed preparation room, acquisition room etc.) are being built. Some of the rooms (seed lab and seed preparation room) are currently functional. The review team has discussed the design plans of the new genebank and made some suggestions for improvement in the workflow through the new facility and reducing any risk for the seeds to absorb moisture during seed handling in drying and packaging. **The reviewers recommend:**

- **The drying and seed packaging should be done in a RH controlled area next to the LTS cold room**.
- **Seed acquisition and temporary holding should take place in the room currently designated as drying room.**
- **As in Taiwan, the distribution seed packs from MTS should be stored in individual freezers.**

The existing MTS genebank is well protected and there are adequate security measures in place to guarantee its protection and safety of the collection. The door leading to the MTS cold room remains locked and only authorized personnel have access. It is important that all security measures in the new LTS genebank relating to access, alarm system for monitoring temperature and RH in cold rooms, and safety of personnel working within the cold room are well covered. There is also provision for two cooling equipment that we will operate alternately to ensure that there is continuity should one break down.

The genebank is well equipped in general and all equipment is functioning well. There is however some equipment that would need to be acquired to improve the genebank operation, such as two functional germination cabinets with light and temperature control for viability testing as recommended in previous section. Also seed processing equipment including small thresher for small grains, sieves, light table, seed counter, etc. may be required to improve the efficiency of the genebank operations. Supplies are well taken care of by the regional office procurement unit. A dedicated store of supplies is maintained separately for the genebank and managed by the procurement office in close collaboration with the genebank staff.

The reviewers observed that many accessions in the MTS cold room were contained in large plastic bags in large volumes. It is unclear how many seed bags are destined for actual conservation and how many are for distribution as part of seed kits program and how these functions are distinguished**. The reviewers recommended that seed packs for conservation be transferred to the new LTS, and that the MTS room be used solely for seed kit distribution.**

2.3 Documentation and data availability

Over-all, as with many other aspects in the WorldVeg genebanks, the potential to do it right is there, having adopted the GGCE database. However, the use of this system is limited and the volume and quality of available data, both in and outside GGCE is very low.

2.3.1 Information management system for monitoring and management

The genebank in TWNGB uses GGCE as its documentation system since a few years, and collection management data are now recorded in this system. The inventory data are good and complete and new data regarding viability test and distributions are recorded in the system. For some reason, legacy data has not been uploaded in the new system, many of the results of viability tests and records of past distributions are still available in the old system or in other files and formats. Attempts should be made to make the data in GGCE as complete as possible, to allow analysis of viability and trends in use, etc. The passport data in GGCE is of relatively low quality (PDCI of 5.44), and attempts should be made to increase the quality by using all sources available, both digital and printed. Characterization data are directly uploaded to Genesys, and not stored in GGCE. Genesys is not a DBMS for this type of data, managing the characterization and evaluation data in GGCE should be considered a preferred option as it allows easier internal use. The export of data from GGCE to Genesys (passport and characterization / evaluation data) or the ITPGRFA Secretariat (SMTA transactions) can be automated if this is not already done in GGCE. The human capacity to work with GGCE is very limited, and as described above, the data included are far from complete. As a result, the distance between this important management tool and the curators / genebank manager is very large. The distance should be reduced by training the staff members in using the system and creating functionalities of direct use by these staff members. For example, if an error or omission in the passport data is observed, the curator should be able to directly correct it. The curators should feel ownership of the data, and work on improving the quality.

The current documentation and data availability of the collection at TZAGB is far from optimal. GGCE is used for the passport data, other types of data are stored in Excel spreadsheets that are loosely linked. To retrieve data, sometimes the accession (RVI) numbers must be used, and sometimes the accession name in combination with the crop is needed. Data is scattered in files or sheets that are sometimes stored per year. As a result, retrieving data is very difficult, and the quality of the data, in terms of meta-data, is difficult to judge. The seed bags are labelled in a variety of ways and the use of consistent QR coding has only recently been introduced and cannot be judged yet. Barcodes are not used in regeneration or viability testing. The limited data that are included in GGCE are shared with Genesys, as are limited datasets with characterization data. Without knowledge of the numbering-system it is not possible to distinguish between material in TZAGB and TWNGB as all data is labelled as coming from TWN001 (WorldVeg). The passport data have a very low PDCI score (4.11) and are thus very incomplete – often essential information such as the sample status (variety, landrace, etc.) is lacking. The availability of characterization and evaluation data is extremely limited – and could not be evaluated due to the confusing numbering system.

Generally, there is a need to improve genebank information management in both sites. **Thus the reviewers recommend;**

- **Migrate all legacy data to GGCE to fully utilize in the efficient management at both TNWGB and TZAGB**
- **Recovery of legacy passport data from previous databases and available documents in both TWNGB and TZAGB**
- **Capacity building in documentation and GGCE utilization locally in both TWNGB and TZAGB**

2.3.2 Security and availability of germplasm data

The backup of the data is secure. The GGCE data are stored, together with the data from WorldVeg Taiwan in the cloud. The genebank data are on the WorldVeg / GGCE servers or on the Genesys servers. These servers can be assumed to be properly backed up and thus sufficiently secure. All passport and characterization data are available in Genesys and thus publicly on-line accessible.

The various files on the various computers are not stored on local discs, but on shared WorldVeg servers that can be assumed to be properly backed-up. However, the risk of unintentional actions with or in the Excel files is considerable and better database management practices are, also for this reason, very important.

3 Key performance indicators

The status of the key performance indicators is given for TWNGB, TZAGB and overall in Table 3. The status for all the individual indicators is given in Annex 2. A very low proportion of the collections in both locations are available currently for distribution. This is mainly due to the low proportion of accessions that have been viability tested (36% for TZAGB and 6% for TWNGB). Of those tested, only 21% in TZAGB and 54% in TWNGB of the accessions had viability above 85%. The proportion of the collection with quantity known (based on number of seeds) is low in TZAGB (22% of accessions) but high in TWNGB (75% of accessions). The proportion of the accession with clear legal status in the MLS is high in both locations (nearly 85% overall). WorldVeg has significant constraints for meeting the 90% target for availability at both locations with a significant backlog in viability tests as well as the poor quality of the seed currently being conserved. The low proportion of accessions with adequate seed is also a bottleneck in TNZGB. In both locations, the number of accessions that will need to be regenerated will also be a significant bottleneck to meet this performance target.

Table 3. Status on key performance indicators

ID	Indicator*	TWNGB	TZAGB	Overall
	Availability of germplasm			
1	% collection, legally, and physically available for distribution (clean, viable, and with sufficient quantity)	7.5	3.2	3.6
	Safety duplication of germplasm			
2	% of the seed collection held in long-term storage at two locations	14.2	66.9	62.7
3	% of the clonal collection held in cryopreservation at two locations	na	na	na
4	% of the clonal collection held in slow growth conditions *in vitro* at two locations	na	na	na
5	% of the field collection, also held in *in vitro* and in cryo	na	0	0
	Documentation and data availability			
6	% collection with passport data available online	100	100	100
7	Average crop PDCI >6.0	4.11	5.44	5.38
	QMS			
8	Number of elements of QMS in place (out of 8)[+]	2	2	2

**Refer to Annex 2 for baseline figures. Consider crop disaggregation where relevant.*

+The 8 key QMS elements are: 1-Science & Operations, 2-Policy, 3-Risk, 4-Staff, 5-Equipment, Infrastructure, & Reagents, 6-User satisfaction, 7-Information management, 8-Suppliers & Services. See Figure 1 in Lusty, Charlotte, Janny van Beem, and Fiona R. Hay. 2021. "A Performance Management System for Long-Term Germplasm Conservation in CGIAR Genebanks: Aiming for Quality, Efficiency and Improvement" *Plants* 10, no. 12: 2627. https://doi.org/10.3390/plants10122627

The status of safety duplication is high for TWNGB for the seed accession but not the field collections in TWNGB or the seed collections in TZAGB. Both locations have passport data published in Genesys but the completeness of information shared is inadequate. While WorldVeg has developed all 8 elements of QMS, only 2 have been completed and approved.

It should be noted that these KPIs are calculated based on the full inventory of 'accessions' in the two genebanks. If the rationalization, as proposed by the reviewers, is performed, the number of accessions will be (much) lower and the values of the KPIs might change considerably.

4 Proactive management of collection

The reviewers observed staff to have a high level of knowledge and skill across all activities during the site visit. The reviewers did not observe many quality assurance practices across genebank operations

in either location. Only TWNGB was putting QR codes on labels but not using scanners and electronic devices to assure identity or track activities through all genebank processes. There was no integration of workflows with the GGCE database for greater automation or increased quality assurance in place across all activities.

4.1 QMS

WorldVeg genebanks operate under a single Genebank Quality Management System (GQMS) that utilizes the Framework of the Genebank Quality Management System developed by the Crop Trust in 2018. The various levels of the GQMS and the various SOPs are given in Table 4. Level 1 is an overall quality management manual that includes overall management, workflows, and general quality management processes. Level 2 Management procedure or SOPs that have been developed or updated as given in Table 4. Only two SOPs have been updated and approved. The approved Document Control SOP is very clear and comprehensive with all the Annexes included. The approved Collection SOP is very clear and comprehensive, but it lacks the workflow chart.

A review of the old version for some of the SOP, such as regeneration, conservation, and acquisition found that these versions were very comprehensive with workflows, clear descriptions of equipment and processes, helpful photos, workflows with clear decision points, clear policy and clear thresholds for decisions. For example, TWNGB has a very comprehensive SOP from 2019 for the three types of crops, open field, greenhouse, or cages. Each SOP includes the process from identification of the need for regeneration to seed production to post harvest handling to drying/seed cleaning. It describes all the facilities, fields, and post-harvest handling areas. Each regeneration SOP includes the Regeneration Policy in Annex I. This policy is very comprehensive and includes requirements for plot size and number of plants, sampling strategy for harvest, tables for number of seeds required for regeneration and for storage and process for authentication of identity. The tables and most of the processes are crop specific. In Table 4, extracted from the baseline questionnaire, TNWGB indicated that these 3 SOP for regeneration were ‘old’ and that a new regeneration SOP was under development. The ’old’ SOPs seem to have areas that need updating and, in some cases, they have figures and text that refer to ICRISAT crops.

Table 4 Status of SOP procedures in the WorldVeg GQMS

SOP	**Old procedure**	**Status new procedure**	**Changes new procedure since June 11, 2023**
Level 1 Procedure			
Quality Management Manual	Written in accordance with Document Management Procedures (QP-01-001) so no old procedure	Approved by genebank manager	Updated
Level 2 Management Procedures			
Document control	No old procedure	Approved by genebank manager	Updated
Germplasm collecting	Old version of 1 SOP is available	Approved by genebank manager	Updated
Germplasm acquisition	Old version of 1 SOP is available	To be reviewed	No changes
Germplasm distribution	Old version of 1 SOP is available	To be reviewed	No changes
Information management	Old versions of 2 SOPs are available	To be reviewed	No changes
Germplasm regeneration	Old versions of 3 SOPS are available	Under development	No changes
Germplasm characterization	No old procedure	Under development	Updated
Germplasm conservation	Old version of 1 SOP is available	Under development	Updated
Books on quality management			
Risk Management			No changes

SOP	Old procedure	Status new procedure	Changes new procedure since June 11, 2023
Communication			No changes

For the SOP for Acquisition, Distribution, Information Management, Regeneration, and Conservation, the new version that were under development or being reviewed that were shared with the reviewers seem to have limited alignment with the old version and were at the very early stages in development. For processes such as acquisition, conservation, and regeneration, the old versions should be updated and edited collaboratively across the two sites as the first step in the development of the new version. **The reviewers recommend a QMS with well developed and managed SOP's that are built upon previous versions that are developed collaboratively across the locations. Specifically, the reviewers recommend these changes in the QMS and the SOPs:**

- **Assign dedicated quality manager at each site to manage development, updates, audits, etc.**
- **Create an internal auditing system across the two sites.**
- **Record non-conformities and use them to improve processes.**
- **SOP need to comply with International Genebank Standards**
- **Review all SOPs to ensure current activities are reflected in the appropriate building or work area, include the building layout, and reflect decision points to complement the workflow diagrams.**
- **Need to generate SOPs/workflows (for each location if different) and reflect decision points.**
- **All SOPs need to have detailed equipment registers including all maintenance and calibration schedules and suppliers of these services.**
- **Develop crop (or crop group) specific protocols for regeneration, viability testing, authentication, and other processes.**
- **In the Distribution SOP, develop a formal process to solicit feedback from recipients to improve processes and services.**

4.2 Risk management

Risk management is a key aspect of the QMS and has been incorporated into the routine operations for WorldVeg. They have developed a Red Book of Risk, following guidelines from the Crop Trust, it is reviewed, updated, and approved each year. The 2022 version only has a focus on TWNGB in Appendix 3-15, except for contracts given for TNZGB in Annex 3. The reviewers recommend that the Book is updated to include the specifics for both sites.

In Appendix 2 of the Red Book, the Business Objectives are given from 2019 where risks are described, rated, and mitigation actions given. In the Risk Register for the two sites of the genebank, there are four business objectives where risks are categorized but these differ from Appendix 2. Also, in the LTG Business Plan, risks are listed in Table 5.1.1 but not all of these are given in the risk register. A general review of the risk listed in the Risk Register also seems to indicate that there are several current risks for both genebanks that have not been identified or developed mitigation actions, such as loss of viability and genetic integrity. Thus, the reviewers suggest that in the next update of these documents, the business objectives and risks described are aligned in all the various documents and updated in relation to risks the genebanks are now managing.

4.3 Efficiency of genebank procedures

The two genebanks have many opportunities for improving efficiencies. In the baseline, both genebanks recognized the value of improving the genebank information management as well as the value of addressing backlogs in safety duplication to improving efficiency of routine operations. While the reduction in the number of accessions in TWN may simplify operations, it will not increase efficiencies in the long run. The reviewers also noted that some reconsiderations in the use of space in the seed conservation area would improve workflow and better secure the genetic integrity. There are other opportunities to gain in efficiency such as:

- In SOP updates, reconsider workflows to improve efficiency and reduce risk to genetic integrity.
- Fully populate the GCCE database with current and historical data allowing for easier and better management decisions.
- Fully integrate the use of the GCCE into processes, monitoring, and decision making to improve efficiencies.
- Explore opportunities to gain efficiency and to further automate with the greater integration of bar coding.
- Reconsider staff management and staff responsibly to gain efficiencies and secure operations.

5 Effective enabling environment

5.1 Finances

WorldVeg has an overhead rate of 16.4% and does not currently utilize full cost recovery. The overhead covers mainly institution level management, such as Administration, Office of DG, and research management. They are considering utilizing full cost recovery in the future but not now. If implemented it could impact upon the genebank routine budget and thus the implication to the genebank annual cost needs to be considered in the cost study.

There are no issues with the procurement process. There is a Capital Fund that addresses the need for new capital assets across the institute. The cost for equipment repair, maintenance, and replacement is done on an ad hoc basis with no long term plan. **The reviewers recommend that WorldVeg develop a longer term plan for essential equipment replacement and upgrading for the genebanks at both sites**.

WorldVeg charges requestors for the distribution of germplasm from both the genebank and the breeding programs. Annex 3 in the LTG Business Plan describes the seed handling fees that are differentiated for accession from the genebank versus the breeding lines. It also differentiates different fees to different types of users. For the accessions that are designated in the MLS, ITPGRFA Article 12.3 states: "Access shall be accorded expeditiously, without the need to track individual accession and free of charge, or, when a fee is charged, it shall not exceed the minimal cost." The handling fee charged for the accessions seems to go beyond the standard interpretation of minimal handling fees. The handling fee includes the more standard fees that are expected for handling and shipping but in addition, a portion is to 'help defray' the cost of routine operations such as regeneration, viability testing, characterization, and storage. The genebank handles all seed distributions and receives 100% of the fee for accessions from the genebank and 50% of the fee for the breeding programs material. This fee is an important source of funds for the genebanks to cover the cost of the routine operation, including electricity, water, regeneration, and other operational expenses. Reducing the fee for the genebank accessions will have negative impact on the routine operations budget. This was recognized as a risk for the genebank in the LTG Business Plan.

The genebank does not have a dedicated, reliable annual budget for routine operations. Any allocation from the core to the routine operation budget is allocated from the overall core operation budget that is allocated to the Crop Improvement Flagship. The Institute has some core funds but 85% of these are used to cover salary. Thus, the genebanks must depend upon project funds and this is not a sustainable way to cover expenses that are essential for the long term conservation and use. The placement of the genebank within the Crop Improvement Flagship does ensure it is actively engaged with the key internal users but there are also users within all the flagships. The 2017-2025 Strategy depicts the genebanks at the center of the three flagships where it engages with all three equally. **The reviewers recommend improvements in the transparency and allocation of funding of the routine operational budget:**

- **Seed handling fees should align with global practices and international agreements (ITPGRFA Article 12.3b)**
- **The policy for seed handling fees should clearly states which recipients are exempt**
- **Core routine operating funds for the genebank should be allocated separately from any flagship to enhance its sustainability and to reflect its central role for the institute.**
- **WorldVeg should conduct impact studies on use of the accessions to build evidence and stories for long term support of the genebank.**

5.2 Policy

WorldVeg has made a commitment to "make their collection available within the multilateral system of the ITPGRFA". This requires that they clarify the legal status of the accessions conserved in both genebanks but having clear legal status for access is not just an issue for external distributions. It is also an issue for internal users. Germplasm distribution, as described in the LTG Business Plan, is done internally without an SMTA or MTA. If an accession has a clear legal status, then the distribution is done with an SMTA and can be used for breeding or research. If there is no clear legal status, then an accession can be distributed internally only for research, not breeding nor can it be shared externally for breeding. The rationale given for this is that if certain accessions are found to be of interest from the ongoing research, then these would be priority to clarify the legal status. Thus, the genebanks are currently distributing all accessions to internal users, irrespective of the legal status in the ITPGRFA. These accessions still have a legal status with the Nagoya Protocol that could impact on the use of any derived breeding lines. **Thus, the reviewers recommend improved compliance with international agreements in relation to legal status of all accessions for conservation and distribution:**

- **De-accession material from the collection if the legal status does not allow distribution under SMTA**
- **No distribution of accessions without clear legal status to internal and external users.**

5.3 Staff management and succession planning

At both genebanks, many of the staff are new (many recruited during COVID restrictions) and have had limited opportunities to receive additional training or engage in cross genebank learning. The management of the routine task by the staff differs between the two sites but generally it is complex with each position focused on multiple work areas. This is to be expected given the limited number of staff, but the reviewers considered this was not optimal to deal with the significant backlogs in QMS, information systems, and in routine operations. The genebank manager, overall and in Tanzania, are only able to focus a portion of their time on managing the routine operations since they also had significant roles in ongoing projects and in developing new projects. They also had a role in the representation of the institute/genebank and in developing partnerships regionally and internationally. The reviewers appreciated the complexity of their role also in terms of management and leadership. The reviewers also noted that no succession planning had been done and there was no clear longer term plan for capacity building of staff. There is a plan to designate deputies to manage the risk of loss of staff in key positions, but this does not seem to have been implemented yet. Thus, the reviewers recommend:

- Allocating a location manager at each site with a focus on attaining the steady state and maintaining routine operations for the longer term.
- For essential positions, build in redundancies with 'deputies' that are trained to take on the task.
- Develop a staff succession plan.
- In the TZA genebank, recruit for an additional position to allow for a clear reallocate of task for the three areas of operations, which are information/QMS, seed handling, and regeneration/characterization.
- In the TWN genebank, separate the allocation of tasks for the information system/QMS and manage conservation into two positions. The information system position could also focus on both sites as discussed in the LTG Business Plan but there would still need to be a dedicated staff in TNZ initially to fully implement and populated GCCE
- Continue to invest in staff capacity building with pairing staff from Taiwan/Tanzania or from different groups outside the genebank.

5.4 Leadership

The organization of the two genebank sites within a system is managed by an overall Head of the two genebanks located in headquarters in TWN and a Genebank Manager for TNZ. This arrangement seems to work well with excellent leadership regionally and globally. As discussed in the previous section on staff management, both positions have many responsibilities beyond management of routine operations. It might be helpful to ensure consistency to have a location manager or head curator for each site and to ensure they have many opportunities to collaborate and work together. The two managers worked

together well but it was not clear how the TNZ site was managed institutionally, was it regionally or within the flagship or within the genebank?

6 Contribution to the global system of crop diversity conservation

6.1 User engagement

The genebanks have active engagement with many users in Africa and Asia through the flagship, project activities, regeneration, and capacity building. These are a wide range of users, including NGO, communities, and farmers. They have established core collections for 8 crops that are available for distribution and being used. For example, the mini core of mungbean accessions is being evaluated widely. In the LTG Business Plan, there are activities identified that build upon the core collections.

WorldVeg does not utilize a process to get feedback from recipients on the quality of service and seeds provided at either site. **The reviewers recommend that both genebanks increase opportunities to engage with users with feedback about the quality of the information supply, the quality of the services in providing the seed, the quality of the seed and accompanying information, and follow-up studies on use.**

The reviewers found no publication or references to impact studies that have been done on the use of accessions that were sent in distributions in the past. WorldVeg indicated that they had distributed over 700,000 accessions since 1972 from Taiwan. This averages about 14,000 accessions per year for the last 51 years. **The reviewers recommend that follow-up impact studies be done on these distributions, such as that described in Jamora and Ramaiah (2022)[2] for the IRRI rice collection, to identify case studies and evidence for the long term support of conservation for this very important collection.**

6.2 Partnerships

WorldVeg has active partnerships in Asia and Africa as described in the baseline, the presentation given to the review team at the site visits, and the LTG Business Plan. The longer term plans are to "Establish a global partnership to safeguard and use vegetable biodiversity". The reviewers agree that their current strong partnerships in Africa and in some Asian countries could be expanded. Vegetable genetic resources are key components of most of the BOLD national partners collections and there is a need for an international partner with expertise in vegetable genetic resources, especially in conservation. One key need for the many of the BOLD partners is in safety duplication sites but the TWN genebank will not be able to offer black box storage given the strict import/export regulations for Taiwan. Capacity building in genebank management is also another area where their expertise will be critical and opportunities to assist in the BOLD Project should be considered.

6.3 Contribution to the development and implementation of global crop conservation strategies

The genebank has participated in the development of four global crop strategies and in the global meeting to discuss the implementation of the strategies. They have also been involved in several high visibility publications on the urgent need for conservation and use of vegetable genetic resources. WorldVeg needs to consider how they utilize the global strategies in planning and developing projects. There is a need for WorldVeg to consider further participation in global strategies for other global vegetables, such as tomatoes. Given the importance of regional vegetables and their current leadership role in raising the visibility of the need for these crops, the development of multicrop strategies should be considered. The strategy development brings crop communities together for greater partnership opportunities and allows for increased visibility, prioritization and investment of the conservation and use for the crops.

6.4 Next generation conservation

In the plans for the new building in Tanzania, and the existing building in Taiwan, no new technologies are being implemented. The genebank buildings will be simple state of the art with no robots, RFIDs or image based seed quality monitoring. Given the current situation that is probably the best way forward: simple and reliable. Once the genebank has fully implemented international standards and the steady

[2] Jamora, Nelissa and Venuprasad Ramaiah. 2022. Global demand for rice genetic resources. CABI Agriculture and Bioscience 3:26 https://doi.org/10.1186/s43170-022-00095-6

state has been reached, the possibilities to enter the next generation are ample. The fact that the genebank is embedded in WorldVeg creates many opportunities. By participating in projects, possibilities will arise to genotype (parts of) the collection and generate other -omics data. If this is combined with reliable phenotyping and appropriate bioinformatics, this could result in innovative approaches to genebank management and the use of genebank material. This genebank might also become a good place to develop and implement innovative approaches for other genebank activities. However, for now, the genebank in Tanzania should concentrate on rescuing the material, setting up a good genebank and reaching the steady state based on solid and reliable genebank methodologies. The Taiwan genebank only needs to make the proposed improvements to become an important international vegetable genebank.

7 Assessment of the sustainability of the business plan, long-term grant (LTG), and/or long-term partnership agreement (LPA) with the Crop Trust

The reviewers have considered the plans and areas of improvement that have been described in the LTG Business Plan in the development of the recommendations and in this report. WorldVeg recognizes the need to attain the performance targets and other needs for improvement in relation to the LTG and the move to LTP. The five year plan is ambitious, but it does not realistically consider the issues related to the backlogs in improving passport data quality, fully implementing GCCE, viability testing, regeneration, and acquisition. The table on the performance targets needs to be updated to reflect a definition for availability that includes viability above 85%. This will lower the availability to less than 10% so it is not realistic to consider a 95% availability by 2027. This is the case for many of the performance targets.

The backlogs are significant for both sites. It would be helpful if Table 2.1.1 included a column on the backlog. For example, in TZA, if you consider the estimated backlog in viability testing, the rate of viability testing proposed, and anticipated increase of the collection to 15,000 accessions, the genebank will take 13 years to just establish baseline viability for all the accessions. For TWN, the reviewers estimated roughly that it will take nearly 12 years to address the regeneration backlog, if you assume that the viability testing will add significantly to the need for regeneration with the identification of accession that fall below the 85% threshold. **To improve the LTG Business Plan the reviewers recommend:**

- **The table on performance targets be updated and the targets be carefully reconsidered in each year.**
- **Both genebanks develop a plan to upgrade their processes and to address backlogs as part of the Business Plan.**
- **The activities planned for the next five years need to be put in a workplan with milestones that can be monitored.**
- **The LTG Business Plan would also be helped with the addition of a section that proposes a longer term future focus for the collections in terms of the next generation genebank**.

Annex 1 About the genebank review

The Global Crop Diversity Trust (Crop Trust) is commissioning the technical review of international genebanks to help validate the institute's compliance with genebank standards, progress in achieving key performance indicators, and confirm eligibility for long-term partnership agreement. The findings will help identify priority areas for upgrading and improvement to sustain essential genebank operations and ensure the long-term security, conservation, and availability of plant genetic resources.

A roster of experts, with knowledge and experience needed to cover the various aspects of the genebank review, was engaged to conduct the genebank reviews of partners. WorldVeg was reviewed by two experts, facilitated by Sarada Krishnan (Director of Programs, Crop Trust) and Nelissa Jamora. The members of the review panel are:

- *Paula Bramel: Chair of the review panel with experience in conducting genebank reviews with expertise in institutional analysis, diversity assessment, and genebank management.*
- *Theo van Hintum: Reviewer, manager of a National Genebank and expert in the field of genebank methodology.*
- *Ehsan Dulloo: Reviewer, experience in conducting genebank reviews with expertise in institutional analysis, diversity assessment, and genebank management.*

The Crop Trust staff prepared a baseline questionnaire covering institutional, financial, and technical topics and circulated it to partner genebanks. The completed baseline questionnaires were shared with the review panel to provide background information and help the reviewers prepare for the on-site reviews. A review checklist was also provided to the review panel to facilitate the on-site reviews and ensure consistency and completeness across partner genebanks.

The team visited the genebanks in Tanzania from 21 to 25 August 2023, and in Taiwan from 25 to 29 September 2023. The agenda of the visits is available in the table below. The recommendations are listed in Table 1. The reviewers have prepared this report with their expert assessment and recommendations for improvement. A response was solicited from the partner before finalization by the Crop Trust.

Day	Item
1	Introduction by the review panel, Q&A with key staff, including management General introduction to the genebank and institute Tour of genebank facilities Areas for review: Staff, equipment, supplies, facilities
2	Areas for review: Genebank operations, SOPs Areas for review: Documentation and data management
3	Visit field sites Areas for review: Institutional, complete report tables Additional areas for review and other pending issues
4	TR panel consults and discusses recommendations with genebank staff (optional) Time for the review panel to discuss the completion of the report
5	Formal presentation of recommendations to management Time for the review panel to work on the completion of the report

Annex 2 Genebank performance indicators

Indicators	TZA	TWN
Composition		
1. Number of accessions in total	5,623	64,679*
2. Number of seed accessions	5,623	64,679*
3. Number of accessions in in vitro	0	0
4. Number of accessions in cryo conservation	0	0
5. Number of field bank accessions	0	0
6. Number of accessions in in vitro and in field	0	0
7. Number of accessions in in vitro and in cryo	0	0
8. Number of accessions in field and in cryo	0	0
9. Number of accessions stored as seeds, and also in field, cryo, or in vitro	0	214**
Availability		
10. Available for immediate distribution	421	2,081
11. Viability tested	2,042	3,836
12. Viability above 85%	421	2,081
13. Health tested	na	759
14. Adequate seed number	1,209	49,475
15. Included in MLS	5,000	54,272
16. Regenerated or multiplied in last 5 years (seeds)	1,252	4,798
17. Samples subcultured in last 5 years (clonal)	0	0
18. Samples rejuvenated in the field/greenhouse in last 5 years (clonal)	0	0
Safety duplication		
19. Conserved in LTS (seeds)	0	52,250
20. Safety duplicated outside the genebank (first level, seeds)	1,607	43,359
21. Safety duplicated at two locations (two levels, seeds)	800	43,260
22. Safety duplicated at Svalbard (seeds)	800	43,275
23. Field collection maintained in at least two locations	0	0
24. Number of clonal accessions held in cryopreservation at two locations	0	0
25. Number of clonal accessions held in slow growth conditions in vitro at two locations	0	0
26. Number of field bank accessions held, also in in vitro and in cryo	0	0
Distribution		
27. Total distributed internally in last 3 years (within the institute)	522	3,923
28. Total distributed nationally in last 3 years (outside the institute)	131,449	4,612
29. Total distributed internationally in last 3 years	57,298	10,375
30. Number of countries receiving germplasm in last 3 years	8	61
Information		
31. With passport data available in Genesys	5,623	67,610
32. With characterization data available in Genesys	0	18,525
33. Average passport data completeness index	4.11	5.44
QMS		
34. Number of SOPs written	8	8
35. Number of SOPs reviewed and approved	2	2
36. Staff succession/management plan available and maintained (Y/N)	N	N
37. Risk management plan available and maintained (Y/N)	Y	Y
38. Equipment and supplies inventory available and maintained (Y/N)	Y	Y
Use		
39. Number of germplasm requests received annually (average last 5 years)	114	207
40. Regular feedback from genebank users (Y/N)	N	N

* 61838 as of 27 Sep 2023

**Garlic accessions

Annex 3 Review checklist

*Review Assessment Score
0 = Compliant
1 = Minor issues or gaps identified, not likely to impact genebank/QMS standards but would improve the efficiency/sustainability of operations
2 = Major issues or gaps identified, likely to impact genebank/QMS standards and would reduce efficiency/sustainability of operations
3 = Critical issues or gaps identified, impacts genebank/QMS standards and efficiency/sustainability of operations
n/a = Not applicable, not assessed

Area	Factors to consider	TZA	TWN
A. Genebank overview			
1-Staff management			
Adequacy of staffing	1. The genebank has adequate skilled staff to perform key genebank operations.	2	1
Succession planning	2. The genebank takes action to mitigate adverse impacts of staff loss from staff movement (resignation, retirement, promotion).	2	2
Capacity development	3. Genebank staff capacities are kept up to date, and training is provided as necessary.	3	0
Overall assessment	4. Overall assessment for staff management.	2	1
2-Composition of the collection			
Uniqueness and importance	5. The genebank conserves unique and valuable crop collections, including Annex 1 crops (consider crop importance to national country and to global conservation and use).	0	0
Conservation forms	6. The genebank has multiple forms of conservation (seed, *in vitro*, field, greenhouse, DNA) corresponding to different crop types in the collection.	0	2
3-Key performance indicators			
KPI: Collection size	7. The genebank has information/trends on the size and composition of its collection.	2	0
KPI: Availability	8. The genebank has information/trends on the number of accessions that are available for immediate distribution.	2	3
KPI: Data availability	9. The genebank has information on access, availability, and sharing of germplasm-related data through their websites and/or Genesys.	2	0
KPI: Data completeness	10. The genebank uses Multi-Crop Passport Descriptors (MCPD) and/or other descriptor lists.	0	0
4-Supplies, equipment, facilities & infrastructure			
Infrastructure	11. The storage chambers (LTS and MTS) are fit for purpose (i.e., well suited) for their intended long-term future use.	3	1
	12. The seed processing and packing areas are fit for purpose (i.e., well suited) for their intended use.	3	1
	13. The drying room/chamber is fit for purpose (i.e., well suited) for its intended use.	3	0
	14. The seed cleaning area (internal/external) is fit for purpose (i.e., well suited) for its intended use.	0	3
	15. The viability testing area or laboratory is fit for purpose (i.e., well suited) for its intended use.	3	3
	16. For clonal crops, the in vitro storage chambers are fit for purpose (i.e., well suited) for their intended use.	n/a	n/a
	17. Environmental records (light, temp, RH) for storage chambers and drying rooms are maintained and periodically monitored.	0	1
	18. The genebank facilities have safety measures in place (restricted access, cameras, etc.).	2	0
	19. The genebank has a replacement plan for infrastructure and equipment.	0	1
Equipment	20. The genebank maintains a list/inventory of key equipment (computers, balances, threshers, etc.).	0	0
	21. The number, type and condition of the equipment is adequate to carry out activities in the genebank.	2	2
	22. Maintenance, calibration and replacement are periodically performed on key equipment.	0	2
	23. The genebank uses barcoding in the management of genebank operations.	3	1
Supplies	24. The genebank maintains a list/ inventory of key supplies (jars, envelopes, boxes, etc.).	0	1
	25. The quantity and types of supplies are adequate to carry out activities in the genebank	0	0
Field stations and greenhouses	26. The genebank utilizes field stations or greenhouses for regeneration, characterization, evaluation, conservation (for field crops), etc.	0	0
	27. The field station(s) is fit for purpose (i.e., well suited) for its intended use.	2	0

Area	Factors to consider	TZA	TWN
	28. The greenhouse is fit for purpose (i.e., well suited) for its intended use.	0	0
Overall assessment	29. Provide an overall assessment of the adequacy of genebank supplies, equipment, facilities & infrastructure.	2	2
B. Genebank operations			
1-Acquisition			
1 Adequacy of procedures	30. The genebank assesses viability and phytosanitary health upon reception of new material.	3	2
	31. The genebank has post-entry quarantine rules for new materials, prior to introduction into the genebank collection.	2	0
2 Information management	32. The genebank has a protocol for assigning unique identifiers and accession numbers for new materials, prior to introduction into the genebank collection.	3	3
	33. Data and information generated during the acquisition procedure are recorded and entered documentation system in a timely manner.	2	2
3 SOP	34. The genebank has a written acquisition procedure/protocol/policy.	2	1
Overall assessment	35. Provide an overall assessment of the adequacy of the procedure.	2	2
2-Conservation: seed processing, storage, and viability testing			
1 Adequacy of procedures	36. The genebank follows an established protocol for seed cleaning.	2	0
	37. The genebank follows an established protocol for seed drying and testing of moisture content.	1	0
	38. The genebank follows an established protocol for packing samples in containers or envelopes.	3	1
	39. The genebank periodically conducts viability testing.	3	3
	40. For long-term storage, samples are stored at a temperature of –18 ± 3 °C. For medium-term storage, samples are stored at a temperature of 5–10°C.	3	0
2 Information management	41. Samples are properly labeled.	3	0
	42. Data and information required for and generated during the conservation procedure are recorded and entered into the documentation system in a timely manner.	2	1
3 SOP	43. The genebank has a written conservation procedure/protocol/policy.	1	2
KPI: Viability and health testing rates	44. The genebank has information on the viability/vigor and health of the collection.	3	3
Overall assessment	45. Provide an overall assessment of the adequacy of the procedure.	2	3
3-Field genebank			
1 Adequacy of procedures	46. The genebank follows an established protocol for field conservation and regularly monitors the quality of plants.	n/a	n/a
2 Information management	47. Samples are properly labeled.	n/a	n/a
	48. Data and information required for and generated in field genebank are recorded and entered into the documentation system in a timely manner.	n/a	n/a
3 SOP	49. The genebank has a written field genebank conservation procedure/protocol/policy.	n/a	n/a
Overall assessment	50. Provide an overall assessment of the adequacy of the procedure.	n/a	n/a
4-In vitro conservation			
1 Adequacy of procedures	51. Light and temperature regimes are adequate for in vitro culture	n/a	n/a
	52. The genebank regularly monitors the quality of the in vitro culture in slow-growth storage, maintenance of long-term genetic stability, and possible contamination	n/a	n/a
2 Information management	53. Samples are properly labelled.	n/a	n/a
	54. Data and information required for and generated during the in vitro conservation procedure are recorded and entered into the documentation system in a timely manner.	n/a	n/a
3 SOP	55. The genebank has a written in vitro conservation procedure/protocol/policy.	n/a	n/a
Overall assessment	56. Provide an overall assessment of the adequacy of the procedure.	n/a	n/a
4-Regeneration and Characterization			
1 Adequacy of procedures	57. Regeneration practices are appropriate to ensure that genetic integrity is maintained (regarding the origin of seed, number of seeds to be planted and harvested, and pollination control)	2	2

Area	Factors to consider	TZA	TWN
	58. Environmental parameters (e.g., photoperiod and vernalization requirements) of field sites are appropriate for the needs of the target crop(s)	0	1
	59. Field management activities (land preparation, irrigation, rouging, agrochemical applications) are adequate for regeneration and characterization of genebank accessions	0	0
	60. The genebank has methods to authenticate the harvested accessions (i.e., accessions are confirmed as being identical to the original material by means of morphological or molecular characterization).	2	2
2 Information management	61. Characterization data is publicly available, or available upon request.	1	0
	62. Samples are properly labeled.	1	0
	63. Data and information required for and generated during regeneration and characterization are recorded and entered into the documentation system in a timely manner.	0	2
3 SOP	64. The genebank has a written regeneration and characterization procedure/protocol/policy.	2	2
KPI: Regeneration & characterizatio n rates	65. The genebank has information on the number of samples regenerated and characterized annually.	2	0
Overall assessment	66. Provide an overall assessment of the adequacy of the procedure.	2	1
5-Distribution			
1 Adequacy of procedures	67. Prior to distribution, the seed quantity, viability, and phytosanitary status of the samples to be distributed are known/checked.	2	2
	68. The genebank has an established protocol for the preparation of samples for distribution (i.e., sample size is acceptable, accessions are packed in air-tight properly labeled packets, relevant documentation is included, durable packaging is used, etc.)	1	0
	69. Samples are distributed in compliance with national laws and relevant international treaties and conventions.	0	0
2 Information management	70. Samples are properly labeled.	2	0
	71. Data and information required for and generated from germplasm request to distribution are recorded and entered into the documentation system in a timely manner.	0	1
	72. If SMTAs are used in distribution, SMTAs are periodically reported to the Secretariat of the ITPGRFA to fulfill the SMTA provider's reporting obligations.	0	0
3 SOP	73. The genebank has a written distribution procedure/protocol/policy.	0	0
KPI: Distribution	74. The genebank has information/trends on the distribution of its accessions.	1	3
KPI: User satisfaction	75. The genebank requests feedback from users to improve the delivery of genebank service.	3	3
Overall assessment	76. Provide an overall assessment of the adequacy of the procedure.	1	2
6-Safety duplication			
1 Adequacy of procedures	77. Safety duplicate samples are stored in another location (nationally), under the same or better conditions than those in the original genebank, for first level	3	0
	78. Safety duplicate samples are stored internationally, for second-level safety duplication.	3	0
	79. The size of safety duplicated samples is sufficient to conduct at least three regenerations.	0	0
2 Information management	80. Samples are properly labeled.	2	0
	81. Data and information required for and generated during safety duplication are recorded and entered into the documentation system in a timely manner.	1	0
3 SOP	82. The genebank has a written safety duplication procedure/protocol.	0	2
KPI: Safety duplication	83. The genebank has information/trends on the percentage of the collection that is safety duplicated in one or more locations or geographically distant sites.	2	0
Overall assessment	84. Provide an overall assessment of the adequacy of the procedure.	3	1
C. Genebank management			
QMS	85. The genebank implements a system that leads to improvement over time (if applicable, establish which genebank standards and best practices are implemented (awareness of FAO genebank standards and others).	2	1

Area	Factors to consider	TZA	TWN
Information management	86. Information management system is available and used in the management and monitoring of the collection.	2	2
	87. Passport and accession-management data are secured by regular data backups.	0	0
	88. Passport and other relevant data are available and accessible to external users.	1	0
Germplasm health	89. The genebank (or its health unit) maintains and updates a list of quarantine pests and diseases.	3	0
	90. Phytosanitary procedures are followed in germplasm transfers (import and export).	1	0
Risk management	91. The genebank can provide evidence of periodic risk analysis, prevention, response, and mitigation (e.g., natural disasters, human-caused threats, incidences of pests, diseases, cyber security, and biological threats (pandemics).	1	1
Efficiency of procedures	92. Accessions and seed lots are advanced through the genebank workflows at an adequate pace (i.e., they do not remain "in limbo" for extended amount of time).	3	2
Overall capacity	93. The genebank overall long-term capacity to conserve seeds, clonal crops, and field collections is adequate	3	1
D. Institutional areas			
Finance	94. The institution has a clear policy on overhead charges on projects and/or international collaborations.	0	1
Procurement processes	95. The institution has an established procurement process.	0	0
Genebank routine funding	96. The genebank has reliable and continuous funding sources for routine operations (e.g., core vs project funding).	3	3
Policy	97. The genebank/institution adheres to relevant national, regional, and international policies that impact genebank operations (e.g., awareness and compliance with policies in Nagoya Protocol and communication with the Plant Treaty country focal point).	0	1
Leadership	98. The genebank has clear leadership, commitment, and vision for improving genebank operations and management.	0	0
Use	99. The genebank works with farmers and other user groups to promote awareness and use of materials from the genebank.	0	0
Contribution to the global system	100. The genebank works with national genebanks and other partners on crop conservation-related activities.	0	0