Global Genebank Partnership

Genebank Review Report

Institute name:	The Pacific Community (SPC)
Genebank focal name:	Centre for Pacific Crops and Trees (CePaCT)

Review team

Reviewer 1:	Ehsan Dulloo
Reviewer 2:	Badara Gueye

Dates of submission

Advanced draft report	28 July 2023
Final draft report	24 August 2023

Dates of approval

Advanced draft report	Crop Trust: 29 August 2023
	Genebank: 27 November 2023
Final draft report	Genebank: 27 November 2023
	Crop Trust: 03 January 2024

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1 Summary of Review Findings and Recommendations

The Pacific Community's Centre for Pacific Crop and Trees (CePaCT) genebank holds an internationally recognized collection of crop diversity (especially for taro and yam) of great importance for the Pacific region and the world and which is held in-trust as part of Article 15 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). CePaCT has a long-term grant (LTG) agreement from the Global Crop Diversity Trust (Crop Trust), whereby SPC is committed to maintain the standards of the facilities and operations of CePaCT genebank. As part of this agreement, besides receiving regular technical reports from the genebank (Art 6 of LTG agreement), the Crop Trust also undertake program and management review (article 7 of the agreement) to ensure that the genebank is meeting its key performance indicators and is compliant to international genebank standards. In this context, a first independent technical review of the CePaCT genebank was commissioned by the Crop Trust in 2017 (Dulloo and Adkins, 2017) and a second review has now been commissioned to assess progress made on the recommendations of the first review, help validate the institute's compliance with genebank standards, progress in achieving key performance indicators, and confirm eligibility for future long-term partnership agreement (See Annex 1 for TOR and methodology of the review). The findings of this review 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 to its beneficiaries.

The objectives of the genebank review are to:

- Assess progress made since the last review (2017) and updates since 2019.
- Identify needs for further strengthening of the genebank.
- Assess human capacity, equipment, and facilities to operate effectively and efficiently.
- Assess the capacity of the genebank to manage data effectively for conservation and use through GRIN-Global and Genesys.
- Determine the extent to which genebank accessions are being promoted and made available to farmers, breeders, and researchers.

The review was carried out from 29th May to 2nd June 2023 in Suva, Fiji, by the independent review panel composed of Dr Ehsan Dulloo (Chair) and Dr Badara Gueye (Panel Member), facilitated by two members of the Crop Trust, Dr Sarada Krishnan (Director of Programs) and Luigi Guarino (Chief Scientist).

A summary of the main findings and new recommendations is provided in Table 1, and the progress made since the 2017 review is in Table 2 below.

Table 1. List of new recommendations

ID	New Recommendations	Proposed activities to address recommendations	Response of the genebank
1	Improve the identity of clonal diversity and the monitoring of genetic integrity in CePaCT *In vitro* genebank - (section 2.1 refers)	a. Complete the documentation of clonal diversity of all accessions and scan and digitally archive all stored hard copy documents.	Thanks for this important observation. Scanning and archiving all hard copy documentation is in progress. Timeline: We hope to complete this task by the end of 2024. Responsible: Logo.
		b. DArT seq. data should be used to develop a KASP marker array for routine identity validation, duplicate identification of the *in vitro* collections and accessions tracking. The results from the genotyping data	We are working (with Landcare Research NZ) on developing a taro microsatellite genotyping method for this purpose. We suggest continuing with this ongoing activity instead of shifting focus on KASP. Once

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		should be confronted with agro-morphological (and, if available, empirical such as herbarium or indigenous knowledge) data to confirm the conclusion of the identity of the germplasm	genotyping results are available, they will be confronted with agro-morphological and other data, where available, to confirm and validate clonal diversity. Timeline: End of 2024 for finishing current work; thereafter looking into KASP Responsible: Amit Sukal & Curator
2	To maintain and ensure sufficient stock of clean germplasm, it is advised to use meristem dome culture as the preferred explant for clonal crop *in vitro* explant. Further, ensure that key equipment, consumables and the right temperature and light environments are in place for optimal *in vitro* conservation work. (Section 2.1.2 refers)	Routinely use meristem dome culture as the preferred explant for clonal crop *in vitro* establishment to increase the chance of producing clean plantlets, in association with other virus elimination methods. In case there is no possibility of getting the material from the field, the meristem of material already established can also be re-excised and cultured for revitalizing the material and virus elimination	We welcome this recommendation and will implement it after thorough staff training in this new method. Shoot tip culture might be used as a first step to ensure survival of sufficient numbers of explants. Once the accessions have been established in in vitro conditions, we will opt for meristem dome culture for further multiplications. This method will also be used for virus elimination. Where routine meristem extraction doesn't work, we will explore chemotherapy, thermotherapy and, ultimately, cryotherapy for virus cleaning. For plant rejuvenation, we often perform meristem excision. Timeline: This will be a gradual process. Responsible: Amit Sukal & Curator
		Acquire the following key equipment and consumables to improve standards in the *in vitro* work: - Glassware washing machine. - Use of MS powder with vitamin for *in vitro* culture media preparation rather than stock solutions - Culture media dispenser (peristaltic pump) - Aseptic gel for less harmful impact on the skin during hand disinfection - Glass door fridge for culture media storage - Mesh shelving and re-distribution of the A/C in conservation and growth rooms for more uniformity of the culture conditions - Data logger to record and analyze the *in vitro* culture conditions. - Installing the second autoclave in the culture media preparation room should be effective in increasing the sterilizing capacity of the in vitro genebank.	Thanks for this list that can guide CePaCT procurement in the future. We just would like to mention the following: 1. The glassware washing machine has been procured and will become operational during the first quarter of 2024. 2. We will take this on board and use MS powder supplemented with vitamins. 3. A media dispenser has been ordered and we expect to start using it by June 2024. 4. We will look at obtaining and switching to aseptic gel for hand disinfection. 5. We welcome this recommendation of procuring a glass door fridge for culture media storage and try to implement it from 2024 to 2025. 6. We agree to remove the Perspex sheets as the culture vessels are stored in racks, hence are stable on the metal mesh of the shelves. We will measure temperature fluctuations within different parts of the growth rooms. If significant variations are confirmed, we will

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			consult with engineers whether it is feasible to re-distribute the A/Cs in the conservation and growth rooms for more uniformity of the temperature in these rooms. This activity is planned for 2024 to 2025, when the new curator is on board. 7. We have daily, continuous temperature recording in the CePaCT emergency facility (vault). This information is shared daily with the CePaCT curator via email (PDF). The same system will be installed in all growth rooms of the CePaCT in vitro laboratories by 2025 (after completion of the cryo lab). Until then, data loggers will be placed in the growth rooms. 8. We will procure a second autoclave in 2024. Timeline: As individually indicated for each item. Responsible: Curator
		For more uniformity and to upgrade the culture conditions, the windows in the growth rooms should be 'blinded' or closed off, and the culture vessels made uniform (tubes for conservation and bottles for multiplication) for the maintenance of the collections.	We will use black cardboard or stickers to blind the windows in the growth rooms. The difference in culture bottles is mainly because some crops don't do well in test tubes currently used for conservation. We will work on getting larger-sized test tubes so we can use test tubes for all crops in conservation.
		Systematize the rejuvenation process every step of time (10 to 12 subcultures) by re-establishing the plant material of the clonal crops from the field or the SH through meristem dome culture. If there is no field material, the in vitro plantlets can be acclimatized and re-introduced to avoid the disadvantages of the *in vitro* culture process (tissue ageing, hyper-hydricity, variations, etc.).	We have already started the process of planting cultures into the screenhouse and rejuvenating them. We try to achieve this systematically over the next three years to ensure that all cultures are rejuvenated. We will put a process in place to rejuvenate every 10 subcultures.
		For better data records and QMS standards, information on the culture media preparation should be documented in a stepwise protocol form (recipe form to be filled in when preparing culture media) to record all details related to the operation such as the accurate execution of the protocol and the exact quantities added. This information should eventually be integrated into the online laboratory information management system for traceability	This recommendation is welcome, and we will develop a checklist for media preparation to be filled in every time new media is being prepared. We will also discuss with Juan Carlos Alarcon (Crop Trust) the prospect of a media preparation module to be included in the Grin Global Community Edition.

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		Commission two conservation rooms with different temperature regimes (16°C and 20-22°C) and to carry out experiments to determine which temperature conditions is optimal for each *in vitro* collection, explore the use of growth retardant (silver nitrate) in collaboration with partners (such as CIAT and IITA) to help lengthen the subculture duration for more cost-effectiveness and efficiency. Further, a growth room for mass multiplication with a 25-27°C temperature regime should be available.	Currently, there is no room available to implement this recommendation. However, with the construction of the cryolab, another growth room will become available, which could be used to maintain coconut and other crops at higher temperature levels. The use of silver nitrate will be systematically tested on aroids and bele (island cabbage) as part of the PhD programme of Ms. Arshni Shandil in 2024. First results should be available by the end of 2024. There is a plan for a bioreactor room as part of establishing the cryo lab. This room could be maintained at about 25 ºC and could at the same time serve as a growth room for mass multiplication at this higher temperature. Timeline: As individually indicated for each item. Responsible: Logo & Curator
3	More effective and efficient virus and bacterial elimination methods should be adopted to reduce the timeline for cleaning and indexing germplasm at CePaCT genebank and increase their availability for distribution. (Section 2.1.3 refers) 2.1.3	The subculturing of *in vitro* plantlets on endophytes-revealing culture media should be routinely done and incorporated into the conservation procedure of all clonal crops to remove the risk of bacterial infection in the conserved germplasm.	We have obtained the protocol for endophyte culture media and are now incorporating it into our screening. We also evaluate some antibiotics and biocides, such as PPM, to control endogenous bacteria.
		For more accurate virus indexing and faster determination of germplasm virus status (eventually availability), it is recommended to explore, adapt, and routinely implement the NGS indexing method (sRSA), which will allow removing the SH step and shorten the indexing timeline	We have already reached out to CIP to get information on sRSA. They have shared the protocols with us and are also open to providing training. Since this is a new method, we plan to send staff to CIP for training. We are also working with Landcare Research, NZ, to evaluate the protocol to have it operationalized in CePaCT faster. Timeline: During the course of 2024 Responsible: Amit Sukal
4	2.2.1 Continue the establishment of a cryobank at CePaCT as a safer long-term complementary conservation of clonal crops and to increase safety duplication of the CePaCT *in vitro* collection, following optimal cryogenic methods. (Section 2.2.1 refers).	Determine the most efficient cryogenic method for each clonal crop collection by carrying out (or finalizing) cryopreservation experiments.	This is noted. We will work towards this goal once we have a fully functional cryo lab established.
		Define objective (scientifically based) criteria and clear policy for curating accessions cryobanking based on the CePaCT genebank priorities before engaging in routine implementation.	This is noted. The priority crops will be aroids, coconuts, and yam. These three crops have been defined in the agreed business plan (2023-2027) between SPC and the Crop Trust. These same three crops will also be the focus during the second phase of the CePaCT investment plan (2024-2029).

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		The new CePaCT cryobank work area/space should be organized according to the procedure for more efficiency in the long-term storage and safety duplication work. The procedure from CIP and IITA could be used as a model. Based on the protocol setting and the responsiveness of the diversity, the number of propagules (meristems) to be cryobanked should be determined to feed the defined cryobank sections.	This is noted, and we will seek support from CIP and IITA to achieve a high level of efficiency in cryobanking crop accessions for long-term storage and safety duplication. Timeline: During the course of 2024. Responsible: Logo
5	Considering the relatively high cost of starting a cryobank, it will be important to optimize the cryobank facility setup and define objectives and procedures, and share experience with other CGIAR cryobanks (IITA, CIP and Alliance) for the equipment and consumables procurement (value for money, fit-to-purpose, brands and specifications). (Section 2.2.2 refers)	Optimize the cryobank facility setup considering special safety and security measure and compatibility with *in vitro* genebank activities; Clearly define objectives and procedures, and share experience with other CGIAR cryobanks (IITA, CIP and Alliance) for the equipment and consumables procurement (value for money, fit-to-purpose, brands and specifications) for main cryopreservation materials (cryovials, boxes, cryo-canes etc..	Agreed, and we will use existing CGIAR expertise to guide our cryobank facility optimization regarding compatibility with in vitro genebank activities and particular safety and security measures. In consultation with CGIAR partners, we will define clear objectives and procedures for procuring equipment and consumables. Timeline: During the course of 2024. Responsible: Logo
6	Support training of at least two CePaCT cryobank staff at a genebank with a routinely functioning cryobank such as CIP, IITA or Alliance of Bioversity and CIAT. (Section 2.2.3 refers)	Support training of at least 2 CePaCT cryobank staff at a genebank with a routinely functioning cryobank such as CIP, IITA or Alliance of Bioversity and CIAT.	Agreed. Timeline: The training of two CePaCT staff is envisioned at the Alliance of Bioversity and CIAT during the second half of 2024. Responsible: Logo
7	Given that the CePaCT seed bank has only recently been established, there is a need for the CePaCT seed bank to develop an overall conservation strategy and action plan to clearly define the aims and	Develop an overall conservation strategy and action plan to clearly define the aims and objectives of the seed bank and how the regional collection of the crops (focusing on landraces) and native tree species from all the member states of SPC will be managed to fulfill its goal of safeguarding the crop and tree diversity in the Pacific for posterity.	In 2025, the Pacific Heads of Agriculture and Forestry Services (PHOAFS) will finalize and endorse the Agriculture and Forestry Overarching Strategy for the Pacific. CePaCT will be bound to that overall strategy defined by PHOAFS. CePaCT will work with the SPC forestry team and partners in the Pacific region to implement elements of this overall strategy.

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	objectives of the seed bank and how the collection will be managed to fulfil its goal of safeguarding the crop and tree diversity in the Pacific for posterity (Section 2.3 refers)	Before engaging in the germplasm collecting, a full ecogeographic study, including needs assessment, should be commissioned by CePaCT to strategically identify priority crop landraces and tree species that would be targeted for collection in the short, medium, and long term	A consultation and updating exercise regarding priority agricultural crops for conservation and utilisation took place during the recent PAPGREN meeting held in September 2023. The results of this consultation will guide future collecting missions during the next 5 years. Timeline: 2024-2029 Responsible: Logo
8	Redesign the workflow of the seed bank operations (seed cleaning, viability testing, seed drying, seed packaging and storage) and reorganize the configuration of the seed lab such that relevant activities are carried out in the correct environment and improve the seed conservation facilities (Sections 2.3.1, 2.3.3, 2.3.4, 2.3.8, 2.3.9 refer)	Separate activities of seed cleaning, viability testing and seed drying, moisture content determination, seed packaging and storage to different locations.	Thanks for this important observation. We will work towards clear demarcation of areas for the different processes. The current seed lab will be reorganized to better separate activities (see also below more on seed cleaning) that have different requirements (e.g. dry environment for seed drying vs use of water for seed germination and some seed extraction activities). Timeline: 2024-2025 Responsible: Curator.
		Seed cleaning: As an initial measure, the shed at the back of the genebank be used for seed cleaning; in the medium term a more permanent seed cleaning area can be developed on top of the cryolab once constructed. Basic seed cleaning equipment should be procured.	Thanks for this important observation. We plan to upgrade the shed to function as the location for seed cleaning. Given the large amount of different wild species that the seed lab deals with, several cleaning procedures cannot be automated and will likely continue to be done manually. On the other hand, purchasing seed cleaning equipment, such as airflow seed sorting machines, will be considered to ease seed cleaning of some tree species with large number of accessions.
		Seed viability testing and monitoring: For any new native tree species received by CePaCT for which the seed storage behavior is unknown, tests should be carried out to confirm their seed storage behavior. Further it may be necessary to conduct research to determine the optimum germination protocol for native tree species.	Thanks for this important observation. CePaCT deals with many native wild species for which seed storage behaviour, seed longevity, germination requirements, and many other essential seed traits are unknown. As part of this, we agree that research activities will be fundamental to conserving these genetic resources properly. A research project with FNU (Fiji National University) involving a MSc student is starting to research germination requirements, seed storage behaviour and seed drying protocols of native tree species of the Pacific. Timeline: 2025-2026 Responsible: Curator
		Germination cabinet: Repair or replace (if repair is not possible or not cost effective) the faulty	Thanks for this observation. CePaCT is replacing the germination incubator and is planning to purchase an additional

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		germination cabinet and an additional cabinet with temperature controls be procured for the seed genebank to determine seed initial viability and monitor the viability of seed collection	one. An RFQ (Request for Quotation) on this has already been finalised. Timeline: end of 2024 Responsible: Curator
		Seed Drying: CePaCT should undertake an analysis of the two seed drying options proposed by the reviewers to decide on which option would best suit their needs. The reviewers' preferred option would be to convert the cold storage unit to a drying room (see also seed storage below).	We agree that converting the cold unit into a drying room is the best solution to enhance seed drying at CePaCT. As part of this, the cooling unit was repaired in late 2022, and supply companies for the drying unit were also identified. The RFQ (Request for Quotation) for the dehumidifier is completed. Moreover, a portable Rotronic (water activity meter) was also recently purchased to facilitate testing the equilibrium relative humidity of the seed lots following international standards. Timeline: end of 2024 Responsible: Curator
		Seed packaging: A vacuum sealing machine should be procured because vacuum packing saves space in the conservation freezers.	We agree on this. CePaCT is already working on procuring a vacuum sealing machine for the seed lab. Timeline: end of 2024 Responsible: Curator
		Seed storage: The cold storage unit should be converted to a drying room (see seed drying above). This room could temporarily be used for storing seed lots of the commercial tree species for the short term	We fully agree with this recommendation. We have already been working on this issue and hope it will be finalized soon (See seed drying above).
		Seed Storage: Acquire two additional -20°C freezers (preferably upright freezers available on the local market), one for keeping the active collection, and another to serve as a backup facility. As the size of the collections grow, stand-alone freezers can be procured in the longer term for both base and active collections, as needed.	We totally agree. Quotations for additional upright freezers will be obtained in 2024, and the equipment will be purchased soon (most likely in 2024). Timeline: End of 2024 to 2025 Responsible: Curator
		Regeneration: Discussions be initiated with member states through PAPGREN and other stakeholders for carrying out regeneration and multiplication.	Agreed. We plan to discuss this issue with the Ministry of Agriculture of Fiji and possibly other partners in the region to assist CePaCT with the regeneration of vegetable crop varieties. Seeds of forestry tree species will be recollected from the original source trees to replenish seed stocks. Timeline: 2024-2029 Responsible: Curator
9	As a matter urgency, actions be undertaken to safely	Effort for safety duplication should be made through the following actions:	Agreed. We will continue to develop these partnerships for safety duplication. We hope to finally

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	duplicate all accessions of CePaCT *in vitro* and seed collection (Section 2.4.1refers)	• Finalize partnership agreement for safety duplication with IITA (for yam) as well as other CG centers (CIP for sweet potatoes and Alliance for banana). • Continue to explore other long-term potential for *in vitro*/cryo safety duplication in the region e.g., Government of Samoa and in Noumea New Caledonia. • Establish the cryopreservation facility for safety duplication of the CePaCT *in vitro* accessions by the end of 2024.	establish the cryopreservation facility at CePaCT in 2024 for safe long-term storage and safety duplication of important crop collections. Timeline: 2024-2025 Responsible: Logo
10	Ensure that all genebank equipment is regularly maintained, calibrated, and properly documented, to ensure that all genebank activities are carried out at high standards. (Section 2.4.2 refers)	Equipment: All maintenance done should be properly documented and the due date for the next maintenance be displayed on the equipment.	Noted, and we will put this in place during 2024. Responsible: Curator & Amit Sukal
11	Review the management policy on procurement procedures to facilitate acquisition of genebank equipment and supplies. (Section 2.4.2 refers)	The management of LRD, while maintaining its corporate procurement procedures, should consider the specific needs of CePaCT and review the level of threshold of €2000 for approval by the financial manager, considering specific supplies that are routinely used in the genebank so as not to disrupt the work of CePaCT. Further, the management should also be cognizant of the fact that for any specialized genebank equipment, it may not always be possible to obtain three quotes. In such cases, the evaluation committee should exercise flexibility in its corporate rules	This is now resolved in some form through our new structure which now has three approvers Director, Deputy Director and Ops Manager (has approval of up to EUR2k). We will also look at establishing preferred supplier agreements with vendors who specialize in laboratory equipment. We have done so far with Plant Health lab, just need to extend to CePaCT lab. Timeline: No action required. Responsible: Logo & Azaria
12	Urgently implement GRIN-Global Community Edition (GGCE) for the CePaCT genebank data and information management and regular update of the data shared on Genesys (section 2.5.1 refers)	Set up an inventory, monitoring, and barcode system across all CePaCT conservation collections (including seedbank, field and *in vitro*) to manage all the genebank operations	We are already implementing and optimizing GGCE and barcoding to have everything in place across all CePaCT conservation and distribution activities.
		With the increase in work and responsibilities, set up a formal data management team with the recruitment of 3 staff, including the one already in place	We welcome this recommendation. We are planning to hire an additional staff to assist the documentation and database technician with the increased workload. Timeline: 2024 Responsible: Logo

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13	Pursue the implementation of the different elements of the Quality Management System, building on the good progress already achieved. (Section 3.1.1 refers)	SOPS: The preparation of the 6 mapped SOPs should be completed and sent for audit. It is also suggested that the Conservation SOPs be disaggregated and separate SOPs for seeds, *in vitro*, cryopreservation, and field genebanks be developed. and that the acquisition of seed materials be considered within the Seed Conservation SOP in lieu of the Collecting SOP.	This is noted, and we will work towards developing the SOPs as suggested. Timeline: 2024-2025 Responsible: Logo, Amit, Albert & Curator
		Policy: Finish setting up the list of reference documents, developing the operational policy and finalizing the overarching agreement with The Pacific Plant Protection Organization	Noted. We will work with the PPPO to sort this out. The CePaCT operational policy will be developed in 2024. Timeline: 2024-2025 Responsible: Logo, Curator & Amit
		Staff: CePaCT genebank staff management should be completed with the succession plan such as shadowing that will reduce the impact of key staff resignation by ensuring continuity	This is noted. We will work with SPC HR to make sure that we have understudies for key management staffs so that CePaCT has continuity when a staff decides to move on. Timeline: during the course of 2024-2025. Responsible: Logo
		Equipment Infrastructure &Reagents: Complete the two last aspects of equipment management by completing the calibration schedule (including calibration reports compiling system) and a replacement plan for all the equipment.	Noted. Timeline: We will try to implement these two aspects in 2025. Responsible: Curator, Albert & Amit to work with external expert
		User satisfaction: A user satisfaction survey procedure must be developed and routinely implemented in the CePaCT genebank	Noted. Timeline: To be in place in 2024. Responsible: Logo
		Information management: The setting up of a disaster recovery, data restoration and quality verification system should be developed and implemented	Noted. We will align CePaCT with SPC Operations & Management Division for this task. Timeline: 2024-2026 Responsible: Logo & Albert
14	Continue efforts to engage in regional initiatives, in particular with PAPGREN and other regional and global initiatives such as ITPGRFA, CBD and FAO Commission on Genetic Resources for food and agriculture (section 3.2.2 refers)	Strengthen PAPGREN to allow CePaCT to continue to play its role as regional convenor of the network and influence policies on the conservation and use of PGR. This will also allow a greater linkage of the whole region to the ITPGRFA and global system on PGRFA.	Noted. CePaCT recently (Sept. 2023) convened a regional PAPGREN meeting. The strengthening of partnerships with ITPGRFA and FAO and other regional mechanisms in support of PGR was strong on the agenda. The PAPGREN Charter has been adopted during the meeting. It will be published after endorsement by PHOAFS in May 2024. Timeline: 2024 Responsible: Logo

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15	Develop a staff succession plan to ensure that CePaCT is not understaffed at any time to carry out essential genebank operation, which may jeopardize its operations.	SPC-LRD and CePaCT management to develop a staff succession plan.	Noted and we will work within LRD and CePaCT to develop a staff succession plan. Timeline: End of 2024 Responsible: Logo

Observation: The indicated timelines for implementing the above recommendations are made on the assumption that there will be no funding or staff constraints (unexpected resignations).

Update on the 2017 CePaCT genebank review.
Out of the 22 recommendations made at the 2017 CePaCT genebank review, 15 of the recommendations have been fully or mostly addressed, while 4 recommendations (Rec 4, subculture research; Rec 9, simplification of evaluation form; Rec 13, Twinning arrangement with International Transit Center, Leuven; and Rec 22 safety duplication of breadfruit *in vitro*) have only partially been addressed and two relating to implementation of the barcoding system (Rec 2) and the preparation of the risk management plan (Rec 10) have not been implemented yet (see Figure 1 and Table 2 below for details). Further only 1 recommendation on the hiring of a documentation and database consultant position was dropped.

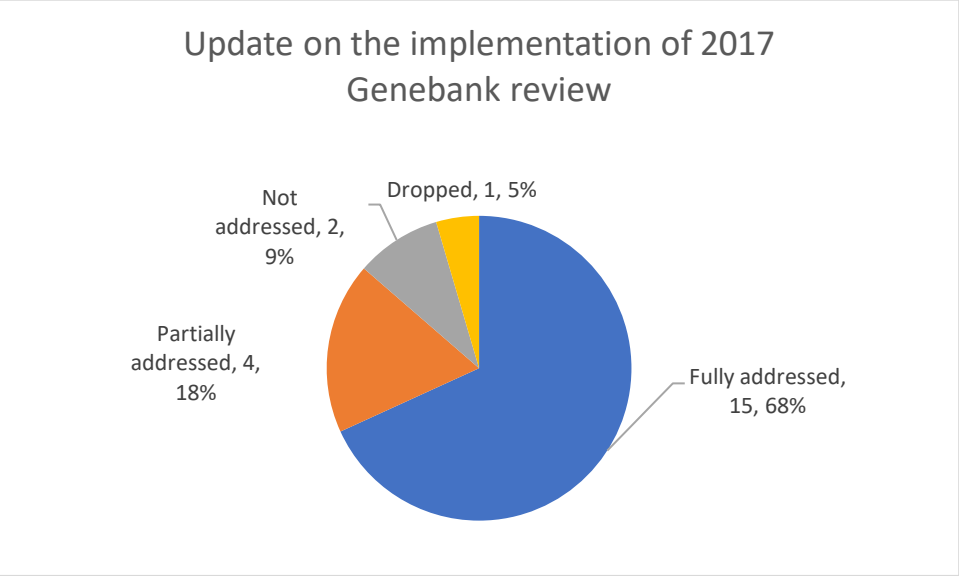

FIGURE 1. Progress on implementation of 2017 review's recommendation.

Table 2. Updates since the last genebank review.

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

ID	Previous Recommendations	Status*	Comments
1	LRD management add an additional thematic area under the Genetic Resources Pillar and the second thematic area reworded to prioritize to the multiplication and distribution function.	**3**	Fully addressed. SPC management considered that there is no need to separate the conservation mandate from the distribution mandate of the CePaCT genebank and made the conservation and distribution mandate of CePaCT much more visible than previously was.
2	Barcoding system be used that can better manage and track the routine	**1**	Barcoding equipment has been purchased and training offered to staff. Trials have been made on

ID	Previous Recommendations	Status*	Comments
	operations applied to the accessions for their conservation.		tree accessions of some tree species in the CePaCT seed bank and giant taro. However, barcoding has not been made operational in the whole genebank.
3	All arriving germplasm should first go into a quarantine holding area possibly the old tennis court alongside the CePaCT laboratory, until viral indexing can take place. Once certified virus-free, materials can then be introduced into aseptic culture and placed into the collection	**3**	CePaCT has constructed a new screenhouse, part of which is reserved as a quarantine holding area.
4	Re-culturing of both active and conservation collections should not go beyond 10 subcultures before new cultures are re-established from newly sourced material from the field or the quarantine collection	**2**	CePaCT considered that this recommendation would significantly increase the cost of CePaCT operations. It was agreed that more research is warranted to develop DNA level monitoring systems for investigating the effect of extended sub-cultures of all the crops, as an efficient step towards reducing the risk of somaclonal variation and ensuring the genetic integrity of the accessions.
5	A documentation and database consultant position be recruited to strengthen the implementation of the barcoding system, advise on the development of the documentation system and ensure a smooth transition towards its application in the genebank	**0**	CePaCT management considered that rather than hiring another database consultant, the CePaCT database manager Albert Fu should receive further training on implementation of a barcoding system at CePaCT and its effective integration into the current database.
6	CePaCT should adopt a number of easily deployable standards for their passport data, including FAO/Bioversity Multi-crop Passport Descriptors, the three-character ISO 3166-1 country codes, FAO WIEWS Institute codes and USDA GRIN Taxonomy	**3**	Fully addressed. CePaCT is now deploying international standards as recommended, as evidenced on the Genesys portal,
7	No distribution be made until due diligence is made of the capacity of recipients to adequately receive, establish and evaluate the materials.	**3**	Fully addressed. Institutions from the Pacific region requesting CePaCT germplasm have been encouraged to undergo hands-on training on the handling of tissue cultured materials at the CePaCT facilities. A leaflet and video on how to acclimatize accession is also provided with each consignment. Staff from most PICTs have undergone training at CePaCT in the handling of tissue-cultured material. CePaCT continues to offer similar types of training to strengthen human capacity in biotechnology in the Pacific region.
8	CePaCT prepare a written agreement for recipients of germplasm for evaluation to sign before any request is approved. The agreement should request the recipient to send a report to CePaCT on the condition of material received and a report on the characterization and evaluation results,	**3**	This aspect is well addressed by CePaCT SOP on distribution, which defines clearly the conditions upon which materials are distributed. (GOF &PCF forms). Under the Pacific Seeds for Life Initiative CePaCT establishes direct links with stakeholders in selected countries on the performance and evaluation of CePaCT germplasm as feedback mechanism

ID	Previous Recommendations	Status*	Comments
	as they become available so as to increase the value of the collection		
9	CePaCT should develop a simpler evaluation data form to help recipients to provide feedback on the evaluation data. As is possible, digital means for capturing information (including photographic images) should be promoted	**2**	Partially addressed. Draft of evaluation form prepared. CePaCT committed to compile minimum description list and evaluation protocols for each of the major crops in the Pacific, which will be published on the PAPGREN and CePaCT websites for wide dissemination within and adoption by the PICTs
10	CePaCT hire a consultant on risk management, with international experience on tissue culture labs to advise and oversee the preparation of a risk management plan and contingency plan. The Crop Trust should be able to advice CePaCT on the consultant.	**1**	Not implemented yet. This activity will be carried out during implementation of the QMS system.
11	A shipping container with power generation be acquired and placed alongside the CePaCT genebank to serve as a refuge for cultures in the event of future natural disasters such as cyclones	**3**	Fully implemented. CePaCT has constructed a fully concrete structure (in lieu of a shipping container for better security) of 20 m2 floor space and with a capacity of 3000 accessions, close to CePaCT genebank. A subset (three cultures each) of all TC accessions will be set aside within the long-term conservation room for easy identification and evacuation into a specially secured concrete structure container, equipped with power supply and connected to a standby generator, in case the path of a cyclone of category 1 or above, has been predicted to hit the CePaCT facilities
12	Given the core responsibilities of the genebank, the SPC should recruit the following permanent positions: • A CePaCT genebank coordinator (international position) • A curator • A documentation and data officer	**3**	Fully implemented. The positions were recruited and were made core staff.
13	A twinning arrangement with an internationally reputable institution be established to allow such exchanges to take place.	**2**	Partially addressed. A twinning arrangement with internationally reputable institution has been explored. An MoU to determine the scope of a twinning arrangement is being discussed between SPC CePaCT and the Musa Transit Center in Leuven, Belgium. Other agreements are in discussions with IITA and CIP. for safety duplications
14	CePaCT explore how it might offer a number of valuable services potentially as a source of income, but not at the expense of the core conservation and	**3**	Since 2016, SPC has been implementing its Full Cost Recovery (FCR) scheme. Since this scheme was made effective, CePaCT is charging FCR for staff time, consumables, shipping and quarantine costs for confirmed germplasm distributions. The same concept will be applied for all other services requested of the Centre including virus indexing of non-CePaCT crops and materials as well as training and capacity building requests.
15	The Pacific Tree Seed Centre be integrated with CePACT and CePaCT genebank and facilities including staff and equipment between the two	**3**	This recommendation has been fully integrated. The Forestry Seed Laboratory is now under the management of the CePaCT.

ID	Previous Recommendations	Status*	Comments
	conservation facilities be shared to mutual benefit under one management.		
16	The CePaCT coordinator position with international experience be filled as a long-term appointment as soon as possible. Besides heading the genebank and being responsible for the overall management of the genebank, the coordinator should also have the responsibility in developing global partnerships with other centers and network and contribute to the global objectives of the International Treaty	**3**	This recommendation has been fully implemented. CePaCT Program Leader is in post and works hard to develop partnership with CG centers, ITPGRFA, FAO, PAPGREN network and other national partners.
17	CePaCT genebank supports SPC member countries in achieving the implementation of the Second Global Plan of Action for the Conservation and Use of PGRFA, as part of the global system, specifically for the priority activities for ex situ conservation, in serving as safety backups for the national collections, in building capacity and in promoting use of PGRFA of importance in the region	**3**	Mostly addressed. A Pacific Seed Forum held in Nadi from 18-23 June 2018 to consult with PAPGREN and other stakeholders on the CePaCT Business Plan and to strengthen the partnership between CePaCT and this network with a view to the safe conservation of underutilized species, safety backups of national collections, and capacity building in the handling of tissue cultured planting material.
18	Humidity within the growth room be monitored and to check to see if the air conditioning is functioning properly and effectively reducing humidity in the room, before purchasing dehumidifiers.	**3**	Fully addressed. Dehumidifiers are in place in growth rooms and in all rooms.
19	CePaCT should carefully evaluate the need for acquiring new accessions of other priority crops consistent to their mandate in relation to threats from cyclones and climate change. However, high priority should still be given to aroids, yams and breadfruit.	**3**	As per CePaCT mandate, top priority is given to aroids, yams, banana, sweet potato, breadfruit, and coconut.
20	A large new container (rather than an old container) with power generation be acquired and strategically located next to the genebank building in the space occupied by the unused “tennis court”. This location is ideal for the quick evacuation of the cultures. This recommendation also addresses the mitigation of risks of natural disasters that are likely to damage the genebank collection. The review team also recommends that this space can be used during safe periods for other genebank activities. (See also Recommendation 3 and 11)	**3**	Fully implemented. This recommendation is being taken care of under # 10. It has been concluded that a concrete emergency seed vault is a safer option than the shipping container and has been implemented.
21	Wire guides or props are installed to support the weak trees and firmly attached in concrete at four opposite sides of each	**3**	This recommendation was fully addressed with wire gauges (no 12 or no 8) attached to treated pine posts (approx. 3-4 meters tall) in straight lines in between each row of trees. Tubing is used to cover each wire where it meets the tree to

ID	Previous Recommendations	Status*	Comments
			avoid injury. This work is supported by the Crop Trust funded GS17004 project. (Final report cyclone Winston).
22	Replicates of each of the breadfruit accessions be propagated and kept in pots in field genebank to be established, as a precautionary measure, in case accessions are lost	**2**	Nineteen breadfruit accessions were targeted under the project for establishment into *in vitro* CePaCT collections of which six 6 accessions were successfully moved to *in vitro* collection (Final report cyclone Winston]. The work was supported by the Crop Trust funded GS17004 project.

2 Assessment of genebank activities to sustain essential operations.

2.1 In vitro genebank

The CePaCT *in vitro* genebank has been established and functioning since 1998 and has been the main conservation system. In addition to its long experience, CePaCT has adequate facilities, skilled staff and equipment that allow appropriate safeguarding and accessibility of the very strategic and important clonally propagated crop diversity, such as aroids and yams, for the region and beyond. The room arrangement allows a cleanliness gradient that is very important for an *in vitro* lab where plant materials are handled aseptically. The CePaCT *in vitro* genebank is functional and adheres to minimum standards that can be improved for better delivery. To meet the targets set up in the CePaCT Business Plan, it will be critical to upgrade the *in vitro* genebank (among other conservation approaches) to higher standards as much as possible and in all aspects as required by the partnership with Crop Trust and other donors.

2.1.1 Monitoring of genetic integrity

A basic principle of plant genetic resource (PGR) conservation for use is the genetic integrity of the diversity conserved. It must be assessed, maintained, monitored, and documented using a system throughout the work-frame. In the CePaCT *in vitro* genebank, the conserved germplasm's identity was determined during the acquisition process in collecting missions and donations essentially within the region. Acquisition data, including taxonomic identity, is available as archived hard copies (collecting books) for the entire *in vitro* collection. It will be necessary to find, consult and document germplasm collection data to complete the documentation (e.g., genetic identity) of the clonal diversity conserved in the CePaCT *in vitro* genebank.

For the verification and validation of the taxonomic identity of the *in vitro* collection, no procedure is in place at the CePaCT *in vitro* genebank. In the context of PGR *in vitro* collection, the only potential and relatively low variation risks are mainly from the presence of growth regulators in the culture media, which are discouraged at the CePaCT genebank. However, during the monthly *in vitro* collection update and screen house (SH) hardening for the indexing processes, a visual check is done to identify and discard abnormal cultures. If the visual check of the plant material can help identify chimeric material, it is surely not reliable to verify and confirm the genetic identity of the germplasm. The optimal procedure would be to use molecular (DArT seq. genotyping) and/or agro-morphological methods to verify and validate the genetic identity of the PGR. Existing empirical data (archived collecting data, herbarium) can also be used to confirm genetic identity, especially when other methods are unclear enough in genetic identity decision-making. Presently, the use of DArT seq. at CePaCT genebank is done through a collaboration with IITA genebank for the yam collection for a co-analysis of the diversity and the yam IITA large collection. Some aroids accessions have been genotyped

in the framework of projects, but this method is not yet routinely used for identity verification. The genotyping method, such as DArT seq., should be used for diversity analysis of the collection and identity/duplicate verification, knowing the issue of duplicates in clonal collections. The genome-wide high-depth DArT-GBS SNP sequencing dataset can be used to develop a Kompetitive Allele-Specific PCR (KASP) marker set for routine identity validation on the *in vitro* collections and accessions tracking.

Once the genetic identity of the germplasm is confirmed, it must be maintained throughout the conservation period with a traceability system based on the monitoring and tracking of the germplasm during all genebank operations. The standard labeling system of the PGR uses barcodes, managed with an online inventory tool (software), for reliable and easier tracking of the plant material. At CePaCT *in vitro* genebank, the labeling is still done by handwriting on pre-printed stickers. According to the FAO genebank standards, handwriting and using Excel sheets as an inventory system are considered suboptimal due to the risks of mislabeling and the difficulty of tracking samples without an online monitoring system (integrating all aspects of the germplasm flow). Setting up an online inventory and monitoring system to track the germplasm through the genebank workflow and operations is imperative and urgent. This will reduce the risk of mistakes, make the procedure easier and bring more efficiency in tracking the germplasm throughout the workflow. Through the Crop Trust, *ex situ* genebanks are encouraged and supported to adopt GRIN-Global Community Edition (GGCE) software. The CePaCT genebank has already started setting up GGCE, but the process should be prioritized and completed to get a functional germplasm tracking system in the *in vitro* genebank.

Recommendation 1: Improve the identity of clonal diversity and the monitoring of genetic integrity in CePaCT *In vitro* genebank.

2.1.2 Maintaining and ensuring sufficient stocks of germplasm.

The *in vitro* conservation system is based on maintaining living plantlets in slow-growth conditions that ensure medium-term storage. The germplasm is established *in vitro* via propagules that respond to the artificial controlled growth conditions (culture media, photoperiod, light intensity, temperature, and hygrometry) to generate the plantlets by organogenesis and regenerated over the subculture process. The recommended initial explant for *in vitro* establishment is meristem dome culture, which allows virus elimination. Virus infection is a major issue in clonally propagated crops due to the virus accumulation over successive vegetative reproduction cycles. Regenerating *in vitro* plantlets through meristem culture increases the chance of obtaining clean and healthy material from viruses. This virus elimination capacity of the meristem culture method depends on the interaction between the host and the virus and can be inefficient in some cases, such as for the host-genome integrated virus, where other virus cleaning methods (cryotherapy, heat therapy, chemotherapy, electrotherapy) can be used in association with the meristem culture method. However, in the virus status of the explant source is already free of viruses, it is advised to initiate *in vitro* plantlets using a shoot-tip explant, which is bigger (meristem dome with few leaf primordia), thus ensuring higher regrowth success.

An optimal *in vitro* conservation system allows viable (growing) plantlets and subculture periods as long as possible for efficiency. Considering the disadvantages of the *in vitro* culture tool (tissue ageing, hyper-hydricity or even risk of somaclonal variations), it is recommended to re-initiate new material for *in vitro* culture or to carry out rejuvenation from the *in vitro* material every 8 to 12 subcultures. The same recommendation was made and discussed in the 2017 review. Despite the justification from CePaCT on the cost implication and the need for further study on eventual somaclonal variations, the point is raised again in this 2023 review as

it is not only about variation but also about avoiding other *in vitro* plant tissue culture disadvantages cited above. In the absence of a field genebank at the CePaCT for new material sourcing, there is a need to rejuvenate the *in vitro* cultures, even if it is by re-culturing the meristem from the same *in vitro* plantlet to avoid the declining of the regenerative capacity of the plantlets, the risk of chimer development and other variations (mutation, somaclonal or epigenetic events). There is a difference in looking forward to studying the eventual presence or extent of somaclonal variations and putting in place a procedure to avoid such events and other issues that may also occur. The commercial *in vitro* plant tissue culture laboratories, dealing with large quantities of plantlets production and usually cited as an example for this aspect, are used to set this quality assurance (QA) measure for eight weeks. More so, the quality assurance and improvement (QA and QI) that this recommendation will bring in the CePaCT genebank make the eventual extra cost quite worthwhile.

Ultimately, *in vitro* conservation is made to ensure the medium-term safeguarding of PGR diversity, making it continuously available thanks to its various advantages: gain of space, useful for other research (somatic embryogenesis, protoplast fusion, embryo rescue, etc.), large and relatively rapid multiplication, the possibility for virus cleaning and safe exchange.

Glassware washing room

The workflow is well-established at the CePaCT genebank, from the washing to the growth and conservation rooms. The two staff dedicated to the glassware washing are overwhelmed with the number of tubes and bottles to handle. With the two autoclaves reserved for the washing room, a glassware washing machine would be necessary to hasten the washing, in addition to being the standard way for glassware washing.

***In vitro* culture media preparation**

The culture media preparation room is managed by two people whose job would be better organized with a recipe sheet where any media preparation would be better planned, followed up, and archived (IITA template shared as example). This would be better as it will give more details on the recipes and the sequential addition of the culture media components during the media preparation operations, compared to the way it is presently. on the recipes and the sequential addition of the culture media components. Another improvement can be brought in the procedure using MS powder, including vitamins, which will allow more standard culture media preparation, and easier and faster preparation compared to the preparation and use of stock solutions, sometimes used too long after preparation. Stock solutions are quite outdated for a routine operating laboratory like the CePaCT genebank. After adding all the components, the *in vitro* culture media must be dispatched in the culture vessels at an indicated volume (e.g., 5 ml in the 16x125 mm test tubes), and depending on the volume to be distributed and the type of container, this step can take time or done improperly. Instead of doing it by hand, the CePaCT genebank should invest in an *in vitro* culture media dispenser, allowing uniform volume dispensing, which is faster and easier for more standards in this step. The last step of the culture media preparation is the sterilization with the autoclaving process at a temperature of 121°C, and 15 psi of pressure for 15 min. At the CePaCT genebank, only one autoclave of a 2 L capacity per cycle is available, making it difficult to prepare more than 5 L of culture media daily. There is a need to install and use the second autoclave for the *in vitro* culture media room for higher capacity and timely culture media preparation per day.

The freshly prepared and sterilized *in vitro* culture medium should be stored for 2 or 3 weeks at low temperatures in a glass door fridge (around 4 °C) until usage. If conserved longer at room temperature, contamination risks from the culture medium are higher.

Plantlets subculture and aseptic handling

In vitro plantlets are kept in growing conditions and should be subcultured once the plantlet overgrows the container. The subculture process in aseptic conditions allows plant material micropropagation (multiplication) and revival. The *in vitro* plantlets aseptic handling and subculture at CePaCT genebank is quite well done by experienced staff. The operation under the laminar flow workspace is done with a strong procedure of label transfer from the old container and the freshly sub-cultured ones. However, the operators are advised to disinfect their hands more regularly and to use hydro-alcoholic gel that may be less harmful to the skin than the 70-90% ethanol solution.

***In vitro* slow growth maintenance (medium-term storage) and multiplication of plantlets**

The newly established plantlets or subcultures are cultured in growth rooms under parameters that favor their growth, whether for slow-growth (conservation) or fast-growth (mass multiplication). The culture conditions that determine the growth for each crop species are controlled by the temperature (intensity and photoperiod), the light and the hygrometry. Ideally, conservation protocol should be improved for rationalization and (cost, labor, and energy) efficiency, allowing as long as possible subculture duration without altering plantlets' physiological state and viability. At the CePaCT genebank, *in vitro* plantlets are cultured in 3 growth rooms, where the first is dedicated to conservation, the second is for mass propagation, and the third is for experiments, bioreactors, and coconut germplasm maintenance. A fourth separated growth room is fully assigned for germplasm under the virus cleaning process with the germplasm health team.

For conservation, all 18 crop collections are kept in one room under the same slow-growth culture conditions at a temperature of 18° to 20°C. It is obvious that all the germplasm collections may not be at optimal conservation conditions, leading to a much shorter subculture duration during the maintenance (e.g., the average 6 months subculture duration is way shorter for yam *in vitro* conservation, compared to the 2 years duration in IITA genebank). Two rooms could be reserved for *in vitro* collection conservation, where one would be at a relatively low temperature (16 °C) which would be more optimal for collections such as yam and *Musa* spp. (banana); and another room where the temperature will be set at around 20-22 °C for other collections. It may be necessary to investigate which collection will be conserved better (longer) in each of the proposed temperature conditions. It would also be worth testing the protocol of growing freshly cultured plantlets under multiplication conditions at around 25-27 °C for 4 to 6 weeks to allow shoot and root initiation before transferring them to conservation rooms. That may benefit the plantlets not to be exposed directly under conservation conditions (growth limitation) while they are just phytomers (only bud between 2 internode sections) without roots and shoots, potentially leading to weak plantlets with short viability.

With the objective of lengthening the subculture duration, a growth retardant such as silver nitrate can be used as a component of the culture media (refer to CIAT cassava *in vitro* collection protocol). This has been quite efficient in increasing subculture duration, from 12 to 24 months on average, in cassava *in vitro* conservation at the IITA genebank.

It is suggested that the A/C units controlling the temperature should be placed on each side of the room (not on the same side), and netting (mesh) shelves be used for better air circulation between the cultures, with a view to increase the uniformity of culture conditions. Also, *in vitro* growth rooms should be “blinded”, i.e., the glass windows should be covered with black paper and made double-glazed to allow easier controlled and aseptic conditions: outside temperature, airflow, daylight “pollution”, entry of insects, ants, or any other contamination carrier. In this respect, using a dehumidifier should be generalized in each growth room to avoid high

humidity, favouring fungus or thrips contaminations. More so, for quality management purposes, the culture conditions should be monitored continuously with a data logger that records the temperature, the light, the hygrometry, and the generated data to be analyzed for adjustment in case of eventual deviations.

For large multiplication, as the CePaCT *in-vitro* genebank has a lot of requests for large quantity material distribution, especially to SPC member countries, the growth room assigned for multiplication should be put under the temperature of 25-27 °C temperature, which will allow vegetative growth. The bioreactors should also be used extensively, considering their high capacity for mass multiplication. The CePaCT *in-vitro* genebank is already equipped with a temporary immersion system, but other systems, such as SETIS® or PLATFORM systems, can be explored for larger production and efficiency, while the RITA® one has relatively lower production capacity and is more suitable for research. Nevertheless, managing the workload between the activities of *in vitro* genebanking and the large production of *in vitro* plantlets for distribution as planting material and seed system requests should be well-defined and delimited to not negatively impact the *in vitro* collection safeguarding. The main activity of the genebank is to maintain the collection, as indicated by the partnership with Crop Trust and the support of the key donors (New Zealand and Australia). For example, much effort should be directed into cleaning the *in vitro* collection to increase the proportion of accessions available for distribution.

Recommendation 2: To maintain and ensure sufficient stock of clean germplasm, it is advised to use meristem dome culture as the preferred explant for the clonal crop *in vitro* establishment. Further, ensure that key equipment, consumables and the right temperature and light environments are in place for optimal *in vitro* conservation work.

2.1.3 Monitoring of germplasm health

A main constraint of the clonally propagated collection is the difficulty of cleaning them from virus infections, which also hinders the transborder germplasm exchange due to phytosanitary regulation. As PGR *ex situ* conservation ultimately aims to make accessible and available the conserved diversity, a major indicator of a genebank performance is the proportion of the collection that is clean from viruses and consequently available for distribution. Thus, germplasm cleaning and virus diagnostic are crucial components of clonal crop GR conservation and use and require efficient cleaning methods coupled with accurate indexing protocol, both aspects to be done in a timely manner, e.g., within an as short as possible timeline. The cleaning is usually done through *in vitro* virus elimination processes that allow virus-free material production, and the health status is assessed through virus indexing.

The CePaCT *in vitro* genebank includes a germplasm health unit (GHU) well-equipped with molecular biology/biotechnology capacity. The virus cleaning and indexing aspects are assigned to the GHU, where the health status of the *in vitro* collection is managed, especially for the main collection of aroids and yam, on which 6 and 3 viruses are tested, respectively. The low proportion of clean germplasm in the *in vitro* collection is mainly due to too long cleaning timeline and sub-optimal virus cleaning protocol. The average lead time for virus cleaning and indexing of accession to declare it available can take up to 12-18 months, including a screen house and *in vitro* re-establishment steps. This is relatively too long, especially when the target is to increase the germplasm availability up to 50 %, at least for a long-term partnership agreement (LPA) with the Crop Trust. There is a strong need to find ways to improve the germplasm cleaning and testing process for both efficiency and the timeline.

For the virus cleaning, the first action should be to systematically use the meristem culture method to eliminate vascular-bound virus. This should be done for all new *in vitro* establishments, and "re-meristeming" should be done on all already *in vitro* established materials. Then to increase virus elimination efficiency, the other cleaning methods can be associated with the meristem dome culture. Heat treatment is widely used as a virus elimination method, as proven in cassava and banana germplasm, and can be applied to incoming material and *in vitro* plantlets. Another virus elimination method associated with meristem culture is using an antiviral agent such as Lactoferrin, Salicylic acid or Ribavirin® in the culture media. Experiments should be conducted to determine which virus-cleaning method combination may be most efficient for each main collection (aroid, yam, cassava, banana). The CePaCT *in vitro* genebank can benefit from experience sharing with other international genebanks in the CGIAR system dealing with clonal crop collections (IITA, The Alliance Bioversity/CIAT and CIP).

One of the major shortcomings of the CePaCT *in vitro* genebank is the non-availability of a big part of the clonal crop collections for international distribution due to germplasm infected with quarantine viruses. The timeline for cleaning and indexing the germplasm at the CePaCT genebank is relatively long: from 6 to 12 for taro collection and even longer for yam. This is due mainly to the necessity to systematically have a shade house (SH) step where the material to be indexed is acclimatized for symptom detection and 2 indexing exercises on *ex vitro* plants as most viruses are likely to be detected with the PCR/ELISA methods. It would be better to accurately detect virus infection from the *in vitro* material, removing the need to acclimatize the plantlet in SH for virus status testing. This can be achieved with the use of sequencing/NGS methods such as the small RNA sequencing and assembly (sRSA)-based virus-indexing method (Boonham *et al.*, 2014 and Pirovano *et al.*, 2015), already used by IITA and CIP genebanks for virus indexing on yam, cassava, and sweet potato germplasm. The sRSA method should be explored and adapted in the CePaCT genebank for faster and more accurate diversity health testing on *in vitro* material and, eventually, the availability of a bigger part of the collections for distribution.

Recommendation 3: More effective and efficient virus and bacterial elimination methods should be adopted to reduce the timeline for cleaning and indexing germplasm at the CePaCT genebank and increase their availability for distribution.

2.2 Setting up of a cryobank at CePaCT genebank

Plant diversity cryopreservation, usually associated with *in vitro* conservation, is a complementary conservation method for clonal crops. It maintains plant material at ultra-low temperatures (in liquid Nitrogen at -196ºC) for a long-term perspective, almost stopping plant cell biological activities and metabolism and eliminating the need to regularly rejuvenate or regenerate the plant. It is the most reliable, cost-effective, and realistic method for Long long-term storage (LTS) of clonal crops, avoiding the disadvantages of irreversible loss of totipotent competencies caused by *in vitro* tissue ageing during successive subcultures, potentially eliminating virus infection contaminants, and reducing the risk of somaclonal variation (Benson, 2008). Cryopreservation is economically more competitive than other conservation systems (Harvengt *et al.*, 2004; Reed *et al.*, 2004a; Keller *et al.*, 2008) and less time and labour-consuming for safer long-term conservation of PGR. In addition, the standards for safety duplication for clonal crops should be from the cryobank, which is considered a key performance indicator in the view of LPA.

The CePaCT genebank has already decided to set up a cryobank for the LTS of the valuable SPC plant diversity. However, this should be done following standards and guidelines that will guarantee a safe, successful, and useful cryobank. The first prerequisite for the setting up of a cryobank is institutional support. The project of a cryobank at CePaCT should be backed up with the full support of the LRD and the SPC in general, with the support of the funding partners (Crop Trust, New Zealand, and Australia) in the global frame of the FAO/ITPGRFA/MLS. According to the strategy of the "Global Cryopreservation Initiative for Clonal and Recalcitrant Crops" initiated by the Genebank Initiative of the OneCGIAR and based on regional cryo-hub around the world, the future CePaCT cryobank is expected to play a major role.

2.2.1. Strategy, Protocols, and Procedures

Creating a cryobank is well-placed in the investment plan developed for the CePaCT genebank but must be well-justified within the global conservation strategy of the center. The complementarity of the different conservation systems (field-, seed-, *in vitro* and cryo-bank) should be clearly planned according to the composition of crop diversity, their importance, and the prospects concerning their availability and use. For example, a cryobank is not made for active collection to be set available for field evaluation or distribution, showing the complementarity and usefulness of the field bank and the *in vitro* genebank.

In terms of protocols, various cryogenic techniques have been developed and successfully used on many crop collections, such as encapsulation-dehydration (ED, Dereuddre *et al.* 1990), droplet-vitrification (DV, Panis *et al.* 2005) and recently, the vitrification cryo-plate (Yamamoto et al., 2011). All these methods have been reported to be highly valuable and efficient for cryopreserving a large range of temperate and tropical crops (Sakai and Engelmann, 2007). The guiding principle has been summarized by Leunufna and Keller (2003), that the main requirements for large-scale and routine use of a cryopreservation technique are that it should be simple, economical, and reproducible and that it should allow relatively high regrowth of the plant material. Considering that successful regrowth is when a fully developed plantlet is obtained after warming and recovery.

At the CePaCT genebank, the priority crop diversity for cryobanking is the coconut, aroids, and yam. Protocol setting and adaptation should be implemented, built upon long scientific collaboration with the Alliance Bioversity-CIAT and other international cryobank centers. A decision-support tool such as the probabilistic equations/model one developed by Dussert *et al.* (2003), calculating the probability of being able to retrieve at least one *in vitro* seedling out of a frozen meristem, can be used to assess the performance of a cryogenic method, in terms of regrowth rate (Dumet *et al.*, 2013). Thus, an optimal cryopreservation method that will allow an effective and relatively high regrowth rate should be defined for each crop collection.

The procedure for the routine cryobanking needs to be defined based on the conservation priority in terms of diversity, safeguarding urgency, and conservation strategy in the long-term perspective of the CePaCT genebank. Firstly, fixing the criteria that will qualify an accession to be cryobanked will be necessary. For example, at the IITA cryobank, an accession must be unique, representative of the diversity (core collection first), virus-clean and amenable to the cryopreservation method.

The CePaCT cryobank will also need to be structured and organized to fulfill the purpose and realize the advantages of this conservation method. Based on CIP and IITA systems, a cryobank mainly entails an LTS conservation part, a temporary and safety duplication parts. The material of each cryobanked accession will be shared in those three parts. In terms of number, 240 meristems are cryopreserved in total at the IITA cryobank (different numbers at CIP cryobank):

120 for the LTS, 84 kept in a separate tank for future safety duplication shipment and 36 in another tank for viability test. The meristems separated for viability test are retrieved 3 weeks after cryopreservation, warmed up and regenerated to determine the regrowth rate. If this latter is lower than 30 %, the accession is considered unreliable for plantlet recovery after long-term storage and should be cryobanked again.

Recommendation 4: Continue the establishment of a cryobank at CePaCT as a safer long-term complementary conservation of clonal crops and to increase safety duplication of the CePaCT invitro collection, following optimal cryogenic methods.

2.2.2. Infrastructures, equipment, and consumables

The specificity of a cryobank lies mainly in using liquid nitrogen (LN), which requires facilities setting, specialized equipment and consumables. All these components are mainly driven by the special safety and security precautions to be considered while dealing with such hazardous elements as LN. Accidents caused by LN can be very harmful and possibly lethal (cryo-burns or asphyxia).

The implementation of the cryobank includes a strong part of *in vitro* plant tissue culture. While the washing and the media preparation rooms can be shared with the *in vitro* genebank, dedicated transfer (subculture) and culture rooms should be planned in the cryobank area. Then, the storage tanks should be assigned a separate room, as well as the LN generator. The organization of the different rooms in the cryobank space should consider the workflow (easy traffic in the space) and the safety measures concerning an in-built air renewal system. The plan to build the cryobank space at the CePaCT genebank should consider all these aspects.

Safety and security measures also drive the equipment of the cryobank for efficient risk management. In addition to the classical equipment for the subculture room and the growth room, the particular equipment is:

- LN generator: the opportunity to acquire one for the CePaCT cryobank needs to be studied against the possibility of contracting a reliable supplier. The essential parameter is to ensure a continuous and indefectible supply of LN to always provide the storage tank as a discontinuity in the LN supply will cause temperature rise, which will alter the viability (or eventually kill) the stored plant material. In the case an LN generator must be bought, the provider (purposely NOBLEGEN, STIRLING C./DH INDUSTRIE, KELVIN, and CRYOMECH) should be selected based on criteria such as quality certifications, easy contact, the possibility of training staff for routine maintenance, offered preventive maintenance, after-sales service, operational verification, financial strength and easy installation of the equipment.
- The storage tanks are a key component of a cryobank, so they must be well chosen considering the long-term perspective of the storage, still keeping the viability of the germplasm. Their capacity to keep the required temperature (always < -165 °C) should be considered, as the type of storage they offer (easy access to the stored samples) and their storage capacity. Very advanced technologies are now proposed by the manufacturer, with tanks offering temperature alarms, simple and easy LN refilling and security access. The way the temperature is maintained and uniformly distributed in the tank is a key factor for an LN storage tank as samples of plant cryobank are mostly stored in the vapor phase of the LN (tank filled up to 15 to 20 cm providing vapor that keeps the samples between -175 to -190 °C). The most famous cryo-storage companies are (CHART-MVE, ARPEGE, CryoTherm-BIOSAFE, Worthington Industries, CryoBioDiffusion-CryoDiffusion).

- For the inventory and monitoring of the cryo samples, a system compatible with the ultra-low temperature should be considered regarding the barcode labels.
- The essential Cryo-PPEs are also necessary for a cryobank for safety requirements: eye goggles or face glass-masque, apron, cryo-gloves, and shoes covering the feet well.

As far as consumables are concerned, the main items are the cryovials and boxes that are used for storing small plant materials in international cryobank (IITA, CIP, Alliance Bioversity-CIAT), such as meristems, pollen, embryos, callus, etc. For stem buds, as for apple germplasm cryobanking, cryo-canes are used at the USDA-NCGRP at Fort Collins (Colorado, USA). Specifically, plant cryopreservation is done with solutions (loading, vitrification, recovery) made with particular chemicals (Glycerol, DMSO and Ethylene Glycol), which are also considered hazardous.

Recommendation 5: Considering the relatively high cost of starting a cryobank, it will be important to optimize the cryobank facility setup, define objectives and procedures, and share experience with other CGIAR cryobanks (IITA, CIP and Alliance of Bioversity and CIAT) for the equipment and consumables procurement (value for money, fit-to-purpose, brands, and specifications).

2.2.3. Skilled and well-trained staff

Implementing a cryobank calls for specialized staff with an well-understanding of the biological and biotechnological basis of the involved processes. Therefore, a strong theoretical background would be advantageous for a cryobank operator. Then, the cryobank staff should be trained in a routinely functioning cryobank, preferably two-way training (in a partner laboratory and back at CePaCT cryobank). This will allow the staff to understand and master the protocols and procedures of plant cryopreservation. At least two more staff of the CePaCT cryobank should be sent to international cryobanks (IITA-Nigeria, CIP-Peru, Alliance Bioversity-CIAT in Belgium, NARO-Japan, NCGRP-USA, etc.) in addition to the CePaCT staff that has been already benefited many training at the Alliance Bioversity-CIAT in Belgium. These partners will backstop, support, and guide the CePaCT cryobank. The trained staff can then train the rest of the cryo-team (train-the-trainers)

Recommendation 6: It is recommended to support training at least two CePaCT cryobank staff at a genebank with a routinely functioning cryobank such as CIP, IITA or Alliance of Bioversity and CIAT.

2.3 CePaCT seed bank

The CePaCT seedbank was established as part of a merger of the Pacific Island Tree Seed Centre (PITSC) with CePaCT program (Centre for Pacific Crops and Trees, Investing in Excellence, 2019). The PITSC itself was created in 2008 in response to the Strategy Action Plan for the conservation, management and sustainable use of forest and tree genetic resources, which the Ministers of Agriculture and Forest approved to collect and share priority tree species among the Pacific countries. It was further recognized that PITSC should not only focus on tree seeds but also other seed crops (traditional vegetables and cereals), which are of high regional importance in terms of food and nutrition security, coastal protection, cultural use, and traditional medicines. This also aligns with the Crop Trust review of 2017 (see recommendation 15, Table 2 above). The main purpose of the CePaCT seed bank is to ensure the conservation and use of priority landrace diversity of cereals and vegetables from SPC member countries and native tree species from the Pacific region. An analysis of the composition of the CePaCT seed conservation collection shows that there are only 7 accessions of tree seeds (of which only

the three native tress species are unique) and a WorldVeg backup reference collection of 124 accessions of vegetable crops. The reviewers think there is no value in maintaining commercial seeds in the long-term conservation collection, as they are not unique and threatened. We believe that with the recommendations of the present review, the CePaCT seed bank can develop into a center of excellence for SPC members to conserve and back up the diversity of the Pacific seed crops and tree species of the Pacific region.

It is the opinion of the reviewers that, although the goal of CePaCT is clear, there has not been much thought given to what and how the seed bank should carry out its work; seed samples are collected or received on an ad hoc basis, without a clear policy on what diversity should be conserved in the seed bank. CePaCT should rethink its objectives on seed conservation at this early stage and develop a conservation strategy to establish such regional collection of the crops (focusing on landraces) and native tree species from all the member states of SPC. We believe that before engaging in germplasm collecting, a full ecogeographic study, including needs assessment, should be commissioned by CePaCT to strategically identify priority crop landraces and tree species that would be targeted for collection in the short, medium, and long term.

Recommendation 7: Given that the CePaCT seed bank has only recently been established, there is a need for the CePaCT seed bank to develop an overall conservation strategy and action plan to clearly define the aims and objectives of the seed bank and how the collection will be managed to fulfill its goal of safeguarding the crop and tree diversity in the Pacific for posterity. We believe CePaCT is important in conserving the region's seeds, crops and trees.

In the sub-sections below, we present a series of sub-recommendations to help strengthen the capacity of the CePaCT seedbank to fulfil its mandate. They are organized in a way that follows the workflow for seed conservation in the seed bank.

2.3.1 Seedbank operations

The CePaCT seed genebank is at its early stage of development, and several modifications are required to improve its functionality. Currently, the genebank has two rooms. Most seed genebank activities from seed cleaning, seed extraction, germination tests, moisture content determination, and seed drying over desiccants (in desiccators, silica gel or Zeolite) are carried out in the first room. The second room holds a cold room currently maintained at 7°C and used as short-term storage for keeping accessions of forest tree species mainly for seed distribution. The room also has a germination incubator for carrying out germination tests, but the incubator is presently not working. Seed cleaning is also performed in this room. The present configuration of the seed bank described above is not in line with the logical sequence of activities described in the flow chart presented in the seed conservation Standard Operating Procedure (SOP) and should be reviewed.

The reviewers recommend that the seed bank be redesigned to provide dedicated spaces for the undertaking of seed genebank activities in a way that produces high-quality seeds with high initial viability. It is very important that activities that require water, for example, seed extraction of fleshy fruits, preparation of germination test, etc., be carried out in separate environments to activities that need to be done in dry environments where RH is controlled such as seed drying, determination of seed moisture content, seed packaging and seed storage.

Thus, it is suggested that activities requiring water be carried out in the first room of seed bank, which has working benches and water basin for seed cleaning under water and seed extraction

and the preparation of the germinator test. It is not necessary to have RH control in this room. The room should be equipped with at least two germination incubators. The faulty germination incubator should urgently be replaced and ideally a second germinator should be procured to allow CePaCT to undertake germination tests of species requiring different germination and dormancy-breaking conditions.

The second room should be re-organized with working benches to carry out seed drying, moisture content determination, seed packaging, and storage. It is very important to control RH in this room, using an air conditioner, for example. All equipment required for seed drying and monitoring moisture content (desiccators, oven, digital scale etc.) and the long-term storage freezer should be moved in this room. A suggested workflow is presented in Figure 2).

Recommendation 8: Redesign the workflow of the seed bank operations (seed cleaning, viability testing, seed drying, seed packaging and storage) and reorganize the configuration of the seed lab such that relevant activities are carried out in the correct environment and improve the seed conservation facility.

2.3.2 Acquisition and germplasm health

When seed samples arrive at the genebank, all the collecting documentation and phytosanitary authority is contacted for inspection. After the phytosanitary requirements are met, the materials are registered and given an accession number and then sent for cleaning, seed moisture determination, and viability testing. The associated information (collecting and passport data) are then entered into an Excel sheet and eventually into the CePaCT genebank database. Standard operating procedures should be developed urgently and be incorporated in seed conservation SOP (see recommendation 13)

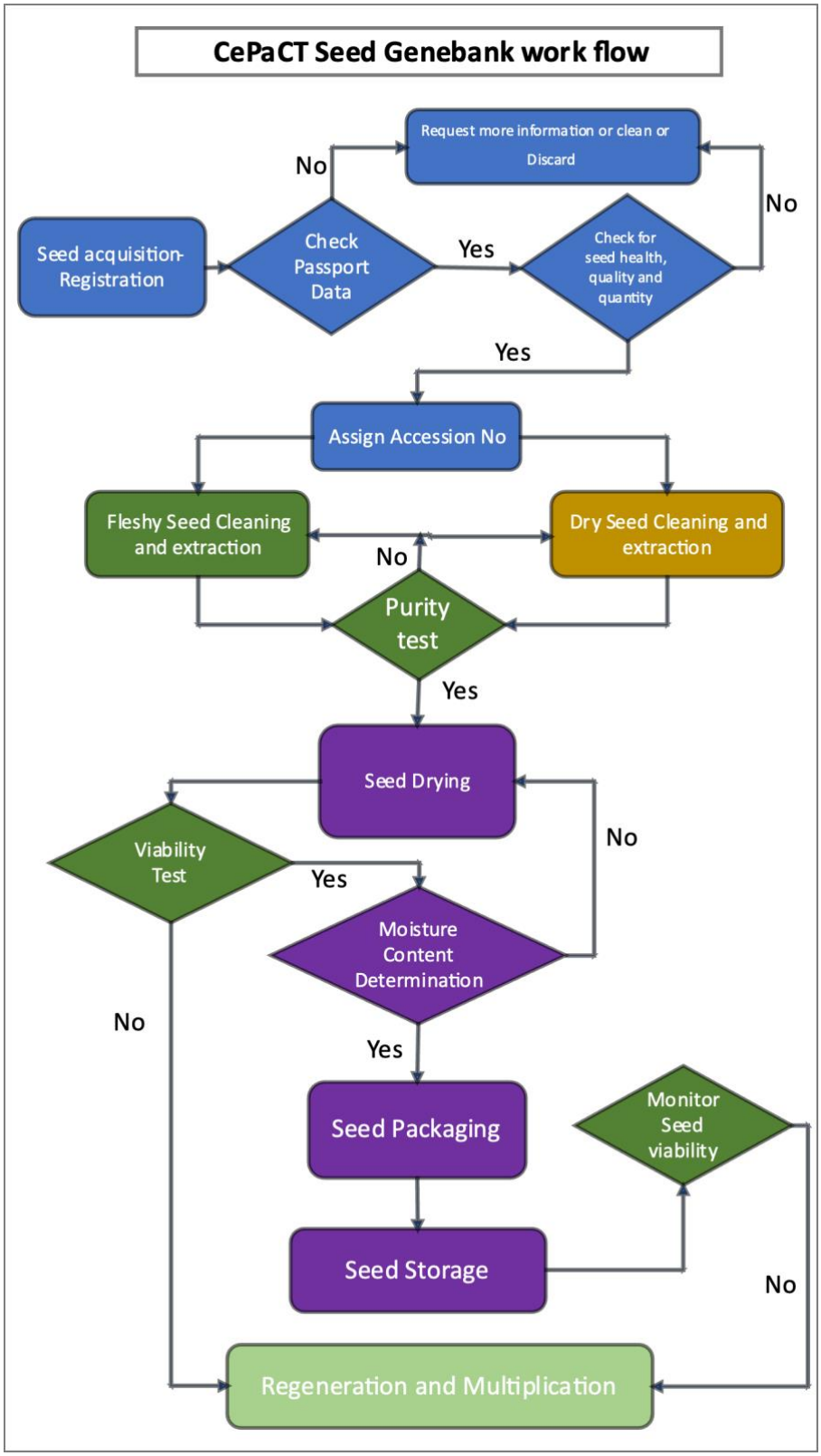

Figure 2. CePaCT Seed Bank workflow.
Colored boxes indicate locations where genebank operations take place. Blue: Office; Brown: Cleaning area; Green: Seed lab; Purple: Drying and storage room. Light green: in the field or greenhouse.

2.3.3 Seed cleaning

Currently seed cleaning is undertaken manually within the seed laboratory where seeds are being processed for storage. This is unsatisfactory as seed cleaning, particularly for crops/species that have dry fruits produce a lot of dust which can be unhealthy for staff. It can also be a source of pathogens and contamination of the clean materials in the genebank. Seed drying is best carried out in a protected facility outside the genebank, where seeds are received, examined, treated, and cleaned. During the site visit a shed structure with benches at the back of the genebank was identified where seeds could be received and initial cleaning carried out. This structure could be reconditioned to make it pest proof (rodent, birds, insects etc.) to protect seeds from predation and diseases. Another option is to consider constructing a shed above the new proposed cryopreservation building and where some cleaning equipment (yet to be procured) could be placed. It is also observed that the seed genebank lacks some basic seed cleaning equipment which can greatly improve the efficiency of seed cleaning and increase seed quality and purity. These should include a small seed thresher for dry fruits such as cereals, a seed blower for separating inert materials from the seeds, and a light table for seed examination to identify empty cells and improve seed purity.

2.3.4 Seed viability testing and monitoring

The CePaCT genebank is called upon to handle both seeds of crops as well as native tree species. For many tropical and subtropical native tree species, the seed storage behavior may be recalcitrant (i.e., sensitive to drying and low temperatures) and not amenable to seed conservation. Thus, for any new species received, it is important to check if they are recalcitrant or orthodox (tolerant to drying and low temperature) and, if unknown, their seed storage behavior should be determined using standard protocols (Hong and Ellis, 1996).

In CePaCT, seed viability testing is carried out by seed germination tests on filter paper or agar in petri dishes and done in 4 replicates using 25 seeds. The petri dishes are then placed in a germinator cabinet (Tris -495-1-sd) set at alternating temperatures 30/25°C and 12 hours photoperiod. Given the diverse nature of the crops (cereals, legumes, vegetables etc.), crop wild relatives and native tree species that CePaCT seedbank handles, it is important that the lab can carry out germination tests under different environmental conditions. It is noted that the germination cabinet is broken and not functional at the time of the site visit. It is urgent that the germination cabinet be repaired or replaced and an additional germination cabinet be procured to provide different germination conditions. Further, there are challenges with the germination of native tree species (dormancy, germination conditions) for which seed germination protocols have not yet been developed. Thus, new protocols need to be developed to be able to determine their seed viability.

The seed viability of accessions should be monitored regularly to determine if their viability has declined. The interval for monitoring would depend on the crops and tree species and their initial viability. In general, for crops, viability is done every 5 to 10 years (FAO, 2014). For tree species, it is recommended that seed viability is tested every 10-15 years. As the seed bank is recently established and barely operational, monitoring of seed viability is not an urgent issue at the moment.

2.3.5 Seed drying

Seed drying is an essential and critical step of seed banking, as it determines how long seeds will survive in storage. As a rule of thumb, the drier the seeds, the longer their longevity will be. Consequently, it is very important that proper drying facilities be available in the genebank. Currently, CePaCT genebank is drying seeds over desiccants (silica gel and Zeolite beads) in desiccators. While this practice is good, using a proper drying machine will significantly

improve the drying efficiency and allow larger quantities of seeds to be processed. This will allow for more efficient and rapid drying and improve the seed viability and quality of the seeds. There are a couple of options that CePaCT could take to improve the drying process.

1. a new seed dryer of appropriate size (to meet its needs for seed drying) and with temperature and Relative Humidity (RH) control (that can be set at 15-20C and 15-20%RH) could be procured. Most genebanks around the world use Munters drying units, but it is important to consider a model for which there is ready access to after sales maintenance in Fiji so that ready intervention can be taken for repair if it breaks down.
2. The cold room (ML-CON2300) currently used for short-term storage is largely underutilized and could be converted into a drying room by fitting a dehumidifier and controlling the temperature and RH to 15C/15% RH in the cold room. The seeds stored in the cold room could easily be moved to a standalone -20C freezer (see section on seed storage). This is the preferred method, providing much space for efficient drying. There would also be enough space to keep seeds in bulk destined for distribution over a short period.

CePaCT should analyse the two seed drying options proposed above to decide which option would best suit their needs. The reviewers' preferred option would be to convert the cold storage unit to a drying room (see also recommendations under seed storage).

2.3.6 Seed moisture content (SMC) monitoring

It is important to monitor the seed moisture content during the drying process. CePaCT uses both a destructive gravimetric oven method (which provides accurate SMC) and a non-destructive method using TinyTags data loggers to determine the SMC of seed samples. This can be improved by using better-performing humidity measuring instruments such as the Rotronic. It is understood that the genebank curator has ordered this equipment already. It is recommended that this equipment be regularly calibrated and checked against the gravimetric method.

2.3.7 Seed packaging

Currently, CePaCT uses different containers for conservation (small screw-capped glass vials, tri-laminate aluminum foil and Ziploc plastic bags). It is essential that the containers used should be hermetic. The preferred container is a tri-laminated aluminum foil which should be of high quality, especially for long-term conservation. Currently, the Aluminum foil bags are not sealed under vacuum, which takes more space in the freezers. To maximize the storage space, we suggest that sealing be done under a vacuum. It is important that the seed packing activity be undertaken in RH -controlled environment. A dedicated space for seed packing should be provided in the drying/storage room (see recommendation on seed bank redesign). Packets are labelled with species name, accession number and provider code. Although a barcode labeling system has been trialed, it is not yet implemented in the seed bank. Given the small number of seed accessions that are presently conserved in CePaCT, the barcode labeling can be readily implemented without much delay (see section 2.5.1).

2.3.8 Seed storage

Currently, CePaCT has a cold storage unit set at 7°C for short-term conservation (active collection). The dimensions of the cold storage room are 2.4m in height, 4m in length, and 3m in width. The room includes 8 shelving units (5 shelves for each unit). Currently, there are 67 seed lots in the cold storage unit. The temperature in the cold storage unit can be controlled, and an alarm system is also installed that can remotely be monitored. Effectively, the cold storage unit is largely underutilized, given its dimension and the number of seed lots/seed

accessions contained therein. Most of these seed lots are in blue barrels and boxes destined for distribution to SPC member countries. Some seed accessions are packed in Ziploc plastic bags and some in aluminum foil destined to be shipped to Kew Gardens Millennium Seed Bank in the UK. Thus, it can be concluded that the cold storage unit is not being used for conservation purposes and none of the accessions are meant to be part of the CePaCT conservation collection. It is suggested that, given its size, the storage room can be used for seed drying. However, it can still be used for short-term storage of seed lots, but every effort should be made to distribute these materials and liberate the space for drying. If they must be conserved for longer periods, they should be transferred into a standalone freezer. We recognized that this is not an issue now as there is hardly any collecting done and receipt of materials for drying is low, but once the seed bank is up and running, space for drying should receive highest priority.

Further, CePaCT has only one -20°C standalone chest freezer, without any alarm system in place, that is used for long-term conservation and constitutes their base collection. The seed accessions are currently stored in three plastic container boxes, containing some silica gel to monitor any moisture leakage (which is a very good practice). Box SL-F-1 contains two accessions of *Pinus caribaea* received from private seed commercial companies from Australia and Brazil, one accession of *Eucalyptus cloeziana* received from Australia and two accessions of native tree species (*Gardenia storckii* (Jale ni veikau), and *Trichospermum calyculatum* (Mako) collected by the SPC tree seed technician originating from Fiji. The *Pinus caribaea* accessions are packed in aluminum foil, while the other accessions are contained in screw-capped vials. Box SL-F-2 contains one accession of *Pinus caribaea* donated by Fiji Pine ltd and one accession of native tree species *Alphitonia zizyphoides* (Doi) collected by SPC tree seed technician. In addition, CePaCT holds a set of 124 accessions of various vegetable crops (such as tomato, pepper, mungbean, cucumber, amaranth, gourds, brassicas, pigeon pea, eggplant, and cowpea) received from World Vegetable Centre as a reference collection of vegetable seeds accessions distributed to SPC countries by WorldVeg. This collection is stored in a separate plastic container box SL-F-3.

The reviewers suggest that the core conservation storage be carried out in standalone freezers. The base collection (meant for long term conservation) and active collection (meant for distribution) should be kept in separate freezers. CePaCT already has one -20°C chest freezer for long-term freezers, which at this stage, has plenty of space, but as the collection increases, additional freezers can be added to the genebank. It is recommended to procure two additional -20°C freezers, preferably upright freezers (to facilitate ready access to accession for distribution for the active collection. Furthermore, an additional chest freezer should be procured to serve as a backup in the event of one of the freezers breaking down. The latter point is very important from a QMS perspective and risk management.

2.3.9 Ensuring sufficient stocks of germplasm.

Regeneration and multiplication

The CePaCT seed bank is not yet faced with the issue of regeneration of its seed accessions, as only very few accessions have recently been put into storage. Regeneration of an accession is required when the viability of a seed accession falls below a threshold (which is 85% for most crops according to FAO international standard, 2019), below which it is expected that viability will have a sharp decline over a short period of time, and thus increasing the risk genetic erosion within the accession. Thus, the viability of seeds in each accession must be regularly monitored, and when it falls below the recommended threshold, the accession must be regenerated (grown out to obtain fresh seeds with high viability) without much delay to maintain its genetic integrity. It should be carried out on accessions kept in long-term storage. Regeneration is the greatest threat to genetic integrity and the most expensive part of genebank activities and must

thus be planned well ahead of time, ensuring that resources, both financial and labor costs, are budgeted well in advance. CePaCT has limited field space to carry out regeneration; thus, arrangements must be made with its partners to undertake regenerations. For example, its closest partner Koronivia Research Station, the Ministry of Agriculture in Fiji has a large expanse of field where regeneration could be done. Partnerships with them and other member states (perhaps through the PAPGREN network) could be developed for regeneration. Accessions coming from Pacific member states could be regenerated in their country of origin. When seed quantities fall under a certain threshold following distribution, the accessions then need to be multiplied to ensure that the genebank has sufficient stocks of germplasm for distribution. Such multiplication is carried out from accessions kept in the active collection. The objective here is to build up your stock for each accession to meet the demands for seed distribution to users. Here again, developing partnerships with stakeholders such as NGOS, or community groups, linking with seed system work of CePaCT can help not only for multiplying its seed stock but an opportunity as well for making available its material to users, enhancing the use of the seed bank material.

2.4 Security of the crop collection and the genebank

2.4.1 Safety and security of the crop collection

The recommended international genebank standard (FAO,2014) for safety duplication states that for:

> Seed bank - "A safety duplicate sample for every original accession should be stored in a geographically distant area, under the same or better conditions than those in the original genebank".
>
> Field collection- Every field genebank accession should be safety duplicated at least in one more site and/or backed up by an alternative conservation method/ strategy such as in vitro or cryopreservation where possible".
>
> *In vitro* collection: "A safety duplicate sample of every accession should be stored in a geographically distant genebank under best possible conditions.".

Currently, none of the accessions in the CePaCT *in vitro* and seed collections is declared as being safely duplicated at two levels in the CePaCT self-assessment report. However, the review has observed that some safety duplications have been made. For example, six of the field accessions of breadfruit have been back up in the *in vitro* collection. These could constitute a first level safety duplication and bringing in all the remaining accessions of breadfruit should be an easy target to achieve in the short term. Further we know from MGIS, that ITC Leuven holds 10 accessions of Musa germplasm in their collection acquired in 1988. CePaCT also reports in their business plan (section 2- genebank 5-year plan) safety duplication has not progressed much due to COVID-19 pandemic, but partnership with IITA is underway for their yam collection. There have also been discussions with the Ministry of Agriculture and Fisheries (MAF), Samoa to host the aroid *in vitro* duplicates, as well as with Noumea New Caledonia. It is important that CePaCT ensure that the services provided by the Government of Samoa meet high quality standards for safety duplication.

Recommendation 9: As a matter urgency, actions be undertaken to safely duplicate all accessions of CePaCT *in vitro* and seed collection.

2.4.2 Safety and security of the genebank facilities

Infrastructure: The CePaCT program is hosted under the Land Resources Division on the SPC campus at Narere Suva. It has a dedicated two-story building with the first floor that houses the reception and staff offices, seed laboratory, a small conference/meeting room, and a tearoom

for staff on the first floor. Access to this floor is open. The seed laboratory comprises two rooms, and both have unrestricted access, which can pose a security risk for accession. The reviewers recommend that once the reorganization of the seed bank is made as per recommendation 17 above, access to the storage room should be restricted.

The ground floor houses the GHU and molecular lab, *in vitro* collections preparation and growth room, indoor screen houses, and two post-quarantine facilities. Access to the entire ground floor area is restricted with a card system in place for authorized staff. However, the ground floor space is organized so that the evacuation of staff in case of emergency may be difficult, especially from the *in vitro* culture lab, as the exit doors are far after the indoor shade house or at the end where the cryobank will be built. The evacuation flow should be tested in alarm drills to ascertain that it is possible for staff to get out of the building within the prescribed time as per SPC guidelines.

CePaCT also intends to expand the ground floor, constructing cryopreservation facilities at the back. It is important that stringent security measures be put in place for the safe operation of the cryopreservation facility. For example, an automatic air renewal system coupled with an oxygen level detector alarm system (sound and visual) could be included in the cryolab design in the event of a spill out of liquid nitrogen. Also, cryo-PPEs should be provided to the staff, such as goggles or face protection, apron, cryo gloves and shoes. All genebank staff, including support staff and first aid warden, should be trained on LN injury handling.

CePaCT depends on the corporate services of SPC for the general maintenance of its infrastructure (see section 3.1.2). The general security is well managed with corporate processes in place that are followed by the CePaCT management team and do not pose any security risks (see also Risk management below).

Field genebank: CePaCT has limited field space for maintaining field collection and to carry out field-based activities such as regeneration, characterization, and evaluation. Currently CePaCT hosts the Pacific Regional Breadfruit field genebank at Nerere. The field genebank is full and has no space for expansion, which limits any future collection. The field collection is exposed to the vagaries of the weather which poses a high security risk. The recommendation of the previous review (Dulloo and Adkins, 2017) for the protection of the individual trees in the collection by installing wire props has been implemented. However, the present review observed that instead of concrete base, CePaCT has opted for treated wooden poles, instead of concrete slab bases. It was observed that some of the poles are starting to rot at their bases which constitute a security risk. Measures should be taken to replace poles and it is recommended that they are sealed in concrete at the base to improve the lifetime of the poles.

Equipment: Generally, the CePaCT genebank (*in vitro* and seed) and GHU labs are very well equipped to carry out all genebank activities at high standards. Most of the equipment is in good order. The good functioning of all the equipment is important, otherwise, it represents a security risk and a key element of the QMS system. Consequently, the regular maintenance and calibration of equipment should be performed regularly. The providers of the equipment service some equipment, but most is not, in which case it is maintained by CePaCT staff themselves. The review team did not find any documentation record of the maintenance.

Recommendation 10: Ensure that all genebank equipment is regularly maintained, calibrated, and properly documented to ensure all activities are carried out at high standards.

In the seed bank, a priority is the repair or acquisition (if repair is not possible) of the germination cabinet. The lack of a germination cabinet poses a security risk to the collection in that seed's viability cannot be tested and monitored, leading to germplasm material loss. The cold storage room is well-equipped with an alarm system and poses no security risk. However, an alarm system must also be installed in the -20°C freezers to monitor the freezer's good functioning. Any new additional freezers should also be equipped with an alarm system to ensure the security of the seed collection.

For *in vitro* genebank as discussed above, and as per recommendation 4, several key equipment such as glassware, washing machine, culture media dispenser, glass door fridge, mesh shelving and datalogger are required for acquisition for the *in vitro* genebank.

Supplies: Supplies are procured following SPC-established procurement procedures for ordering supplies and equipment. SPC is now applying the One-SPC approach whereby all admin procedures are being streamlined, and levels of approvals from the Leader of programs to the Director level are established for purchases following different threshold levels. Thus, for purchases less than €2000 the Financial Manager of CePaCT can authorize (requiring only one quotation), while for any purchase of more than €2000 at least three quotations are required, and approval is provided by the Deputy Director up to €45,000, and above this figure, approval must be obtained the Director of LRD. Many of the supplies routinely used in the genebank often exceed the initial threshold of €2000; thus, ordering supplies can take a long time due to the new One SPC process. However, SPC has a preferred supplier list in which no quotations are needed. It was also noted that a problem faced by CePaCT is the difficulty of finding more than one supplier for specialist supplies and equipment in Fiji, and thus, it is difficult to obtain more than 3 quotations. The quotations received are processed by an Evaluation committee, which decides which is selected based on value for money. SPC also enjoys duty-free status in Fiji, and any purchase requires a clearance process from the Fijian Ministry of Agriculture. It is recommended that the management of LRD, while maintaining its corporate procurement procedures, should consider the specific needs of CePaCT and review the level of threshold of €2000 for approval by the financial manager, considering specific supplies that are routinely used in the genebank so as not to disrupt the work of CePaCT. Further, the management should also be cognizant of the fact that for any specialized genebank equipment, it may not always be possible to obtain three quotes. In such cases, the evaluation committee should flexibly apply its corporate rules.

Recommendation 11: Review the management policy on procurement procedures to facilitate acquisition of genebank equipment and supplies.

2.5 Documentation and data availability

Plant genetic resources *ex situ* conservation in genebank is made accessible and available for crop improvement, research, training, and production, with the ultimate objectives of ensuring food security and income generation for welfare. Thus, plant diversity preservation and use rationales entail several activities, such as germplasm collection acquisition, conservation, characterization, distribution, and training. As for every genebank, for whichever conservation means (field bank, seed bank, *in vitro* genebank and cryobank) at CePaCT, the documentation is pivotal and constitutes the guiding line of all the procedures, which will make possible the management, publicizes availability, and allow access to the conserved PGR for use. The documentation includes all the data generated, collected, stored and exploited at all conservation and use continuum stages. This requires reliable, useful, and efficient online data and information management system for inventory, monitoring and diffusion.

2.5.1 Information management system for monitoring and management

The CePaCT genebank routinely manipulates thousands of accessions and 'lots' between the different genebank operations. Currently, the data from the different genebank operations are captured independently in different excel files that the genebank Database Officer manages. Further, the tracking of these accessions and 'lots' are made manually. This arrangement is not very effective and is exposed to errors. The reviewers strongly recommend that an electronic barcoding system be put in place without delay to document all the genebank operations so that all genebank operations and procedures are seamlessly integrated. All handwritten labels used should be replaced with barcodes. This calls for a barcode system driven by a customized application to automate the samples, lots and accessions tracking in locations and stock. The needed equipment and consumables for the barcode system include labels (with barcode layout designing software for 1D or 2D barcodes), printing technology (transfer or thermal printing), tablets for data capturing, desktop and mobile printers for barcode label printing, wired and wireless scanners for barcode reading. The CePaCT genebank should be equipped with tablets and software developed to allow effective data capturing during genebank operations. All tablets can be linked to the inventory system, allowing offline data upload. A 2D barcode system (QR code, Data Matrix or even Maxi code) is recommended, managed with software and all the genebank operations. The data management system will depend on the type of data stored, its accessibility and utilization. The management system might be in-house or any other global data platform... The activities should be integrated with the data capture, building triggers and alerts for a sequence of activities in the workflow.

The management of the generated data and information from the CePaCT genebank should be recorded in a suitable database for documentation and exchange, such as the recommended GRIN-Global Community Edition (GGCE). As a major standard, all the genebank databases should be stored safely on a server and have regular and automatic backups in the Cloud and/or another server in a different location. One of the main advantages of the GGCE, in addition to being used by most of the community, is to be compatible with the platform for data and information sharing Genesys (https://www.genesys-pgr.org). It is an online platform where information about Plant Genetic Resources for Food and Agriculture (PGRFA) conserved in Genebanks worldwide is shared. The CePaCT genebank has already shared information on Genesys, but it should be regularly updated.

The Central SPC IT unit supports the information technology platform used by the CePaCT genebank and provides necessary maintenance and technical support to the genebank IT unit. For the genebank documentation processes to work efficiently, it is important that the Central SPC IT unit can provide prompt and timely support to allow the genebank to operate properly.

Recommendation 12: It is strongly recommended to urgently implement GRIN-Global Community Edition (GGCE) for the CePaCT genebank data and information management and regular updates of the data shared on Genesys.

Table 3. Status on key performance indicators

ID	Indicator*	Status
	Availability of germplasm	
1	% collection, legally, and physically available for distribution (clean, viable, and with sufficient quantity)	35.55
	Safety duplication of germplasm	
2	% of the seed collection held in long-term storage at two locations	0
3	% of the clonal collection held in cryopreservation at two locations	0
4	% of the clonal collection held in slow growth conditions *in vitro* at two locations	0
5	% of the field collection, also held in *in vitro* and in cryo	0
	Documentation and data availability	
6	% collection with passport data available online	100
7	Average crop PDCI >6.0	4.95
	QMS	
8	Number of elements of QMS in place (out of 8)+	4

**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. Out of the 8 key elements, the policy, Equipment infrastructure, & Reagents, User satisfaction, Suppliers & service has successfully be met, while significant improvements are still required for the Science and operation, Risk, Staff (succession planning) and information management. "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

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

3.1 Proactive management of collection

3.1.1 Genebank QMS

The establishment of a quality management system (QMS) in the genebank is the definition of a "formal framework that uses specific conventions and definitions of terms to delivers and documents the responsibilities, operations and procedures to achieve maximum effectiveness, quality and reliability, with minimal risk, at minimum cost." The CePaCT genebank has been engaged in the QMS journey since 2018 with the support of the Crop Trust, emphasizing on the 8 major QMS pillars (Science & Operations, Policy, Risk, Staff, Equipment, Infrastructure, & Reagents, User satisfaction, Information management, and Suppliers & Services). The set target in the Investment plan is to have full implementation of all the QMS elements by 2029.

The previous 2017 genebank review touched on several elements of the Quality Management System (QMS), including barcoding (rec2), documentation system (rec5), risk management (rec 10), and core staff (rec 12), among others. This present review is pleased to see that many of these recommendations have been implemented that will contribute significantly to raising the performance standards of CePaCT. There is clear evidence that SPC is taking QMS very seriously. Significant progress has been made following a QMS training course offered by the Crop Trust in 2018, where all CePaCT staff were involved. CePaCT has made headway in the development of Standard Operations Procedures (SOPs) covering key genebank operations, inventory of genebank equipment and reagents and instructions sheets for key equipment, and general rules for the laboratory. It is recognized that while some other measures are already in place regarding some elements of the QMS system, like OHS, and infrastructure maintenance human resources, more efforts are required to strengthen them to meet the Genebank QMS

standards. The QMS is generally based on 8 major pillars: policy, science, risk management, staff, equipment/infrastructure/reagent, user, information management and supply chain.

Recommendation 13: Pursue the implementation of the different elements of the Quality Management System, building on the good progress already achieved.

Standard Operations Procedures (SOPs):
The SOP is the main part of the Science & Operations pillar and is defined as a set of instructions that meticulously describe how tasks and operations should be undertaken by personnel assigned to specific responsibilities. The CePaCT genebank identified 11 SOPs covering key genebank operations to prepare (Collecting, Acquisition, Seed drying and storage, Conservation (TC&Field), Germplasm Health, Rejuvenation/Regeneration, Characterization, Safety Duplication, Documentation, and Administration). Of these, SOPs for Conservation and Germplasm health have been drafted and are being reviewed. Further because of the merger of trees seed conservation work with CePaCT, as endorsed by PHOSFS, seed conservation and distribution SOPS were also drafted. A workflow of all genebank operations was also developed with the support of the Crop Trust QMS specialist, based on operational systems, in 2018.

The reviewers have detailed comments on the SOP on Conservation, which currently combines all the conservation activities of the CePaCT genebank (seed conservation, *in vitro*, cryopreservation and field genebank). The details will be provided directly to CePaCT for their consideration. SOPs are critically important and allow a standard way of carrying out genebank by different staff members. They should be prepared for specific activities. It is understood that germplasm acquisition is considered in a separate SOP on Collecting and Acquisition. The acquisition is the first step at the seed genebank when seed samples are received. Its seed quality and health are examined, checks are made if the material is already present in the genebank or not, and decisions are made on whether to accept the register of the sample in the genebank. procedure for its handling must be clearly described so that genebank staff, making more sense to include the acquisition of seed materials within the Seed Genebank SOP. It is suggested that the preparation of the 6 mapped SOPs is completed and sent for audit. It is also suggested that the Conservation SOPs be disaggregated and separate SOPs for seeds, *in vitro*, cryopreservation, and field genebanks be developed and that the acquisition of seed materials be considered within the Seed Conservation SOP in lieu of the Collecting SOP.

Policy:
From the 2018 baseline, the policy aspects to be set up by the CePaCT genebank has not been improved much as the list of reference documents are not in place and the operational Policy have not been developed, but the activity has been allotted funds. The main policy action achieved since 2018 is the development of the rules for all the facilities. However, the CePaCT genebank can count on the support of the SPC legal unit to set up all policy documents and agreements to have full compliance with the QMS policy pillar. It is suggested that setting up the list of Reference documents be completed, the operational policy be developed, and the overreaching agreement with The Pacific Plant Protection Organisation be finalised.

Staff:

Implementing the staff management pillar of the CePaCT genebank has been advanced with the definition of the organigram, the compilation of the key staff CV, the job description of the key positions and the capacity building plan. For the Occupational Health & Safety Manual and considerations, The CePaCT genebank relies on the central SPC safety & OHS unit, which is

taking care of this aspect as instructed by the "one SPC" strategy in progress. The main recommendation for the CePaCT genebank staff management should be completed with the succession plan, such as shadowing, that will reduce the impact of key staff resignation by ensuring continuity.

Equipment, Infrastructure, & Reagents (EIR):

In terms of infrastructure, the CePaCT genebank is managed by the central SPC facility and infrastructure team, which keeps regular maintenance and record-keeping in place. The same unit oversees maintaining, monitoring and yearly reporting of the security of the genebank environment (security access, buildings, alarms, AC units, backup generators, electricity, and water supply) and the physical conditions in the building, including culture conditions (light, temp, RH). Only external inspections of the environment are yet to be put in place. The complete list of reagents is in place for each section of the CePaCT genebank, and their shelf-life is monitored quarterly. However, reception and storage procedures for the reagents and consumables are not yet developed. Most specifics are in place for the QMS aspects concerning the equipment. It is thus recommended to complete the two last aspects of the equipment management by completing the calibration schedule (including calibration reports compiling system) and a replacement plan for all the equipment.

User satisfaction

A plant diversity repository that aims to promote the utilization of the conserved collections, the quality of the service provided by the CePaCT genebank needs to be assessed and adjusted to satisfy germplasm users. This is done through surveys, enquiries, and questionnaires to provide feedback, which will be used to improve the management and the use (distribution) of diversity. User satisfaction survey forms have been developed, but the CePaCT genebank is yet to routinely conduct systematic surveys, and consequently, the yearly report of user feedback is unavailable. Thus, a user satisfaction survey procedure must be developed and routinely implemented in the CePaCT genebank.

Information Management:

This QMS pillar is essential and crucial as it helps to manage and report on all the activities, results, and documentation. It has a security aspect concerning safeguarding the information as all the data captured need to be verified and validated before secure storage and backup. Among the range of data and information to manage, the CePaCT genebank mainly lacks an online inventory and inventory system. This confirms the utmost importance of completing the setting up of GGCE as discussed and recommended above. Otherwise, all captured documentation and information are validated before uploading and backup in SPC cloud facilities. The setting up of a periodical disaster recovery system, data restoration and quality verification should be developed and implemented.

Supply Chain Management:

With all the EIR, the CePaCT genebank needs an efficient procurement system with high standards. With its long experience, the CePaCT genebank has already put in place a list of qualified/certified suppliers and contractors. But the SPC procurement committee does the procedure and contract procedures and the yearly quality and certification assessment of the suppliers and contractors.

All the QMS implementations on the CePaCT genebank activities and procedures need an internal follow-up team, which periodically audits the progress in the setting up of the QMS pillars. This would allow the CePaCT genebank to be better prepared for external audits to demonstrate the efficiency and effectiveness of the well-planned quality improvement plan in the CePaCT Business Plan & Investment Plan.

3.1.2 Risk management

CePaCT is fully supported by the SPC corporate services Operations and Management Division (OMD) and the Occupational Health and Safety (OHS). OMD takes care of all SPC facilities, including CePaCT facilities, and provides services for verifying, maintaining, and servicing its building, electrical network, and generators. However, they do not service individual equipment of the genebank, which is taken care of either by the provider of the equipment where available or by the CePaCT staff themselves. OHS manages the safety and occupational health system relating to major risks, including fire, natural disasters, health, accidents, incidents, and risks (HAIR). Both divisions have detailed procedures available to staff on their intranet page, which comply with Fijian national authorities' standards for fire, natural disaster risks, etc. However, CePaCT does not yet have a Risk Management Plan of its own. Discussions have occurred to develop a specific Risk Management Plan in line with SPC's procedures.

CePaCT building is fully compliant with the corporate OHS standards. Exit signs are well displayed around the building. There are manual call points, firefighting equipment and first aid kits, and a designated assembly area is available. SPC still does not have defibrillators, but will soon be made available. OHS also provides an alert emergency system through emails and SMA to alert staff and their families of any security emergency when they arise. CePaCT has designated staff to serve as first responders for fire wardens and first aid officers to facilitate the evacuation and guide staff according to established guidelines. In case of cyclones - They have a cyclone checklist of the actions that must be carried out under the supervision of the security actors (maintenance supervisor and health and safety supervisor and a form must be duly completed. OHS has a 'HAIR' (Health, Accident, Incident, and Risk) management system in place to deal with the different risk factors.

In addition to the above, CePaCT has identified several specific risk factors for its genebank, including safety duplication as the most critical risk factor, as none of its accessions are safely duplicated.

A natural disaster is the second most important risk to the collection: Regional Pacific Breadfruit field collection. While some measures have been taken to secure the collection following the first review, the collection remains very vulnerable, and CePaCT should accelerate the safety backup *in vitro* and eventually in cryo. As per previous review recommendations, CePaCT has also constructed an emergency vault to secure its accessions during cyclones.

Other minor risks include the continuous supply of electricity, without which the genebank activities cannot function. CePaCT is fortunate that the electricity supply in Nerere is stable, but if electricity fails, it has a backup generator recently replaced with a stronger one and kicks in less than 10 seconds. This was witnessed during the review team visit when electricity was cut, and the generators effectively kicked in about 5 seconds. Discussions are also underway with SPC management to acquire a second generator for the cryo lab. Given its expansion for cryo and the seed bank, this will add greater security to the genebank. The generators are serviced and tested bi-annually by OMD.

3.1.3 Efficiency of genebank procedures

The review fully endorses the concrete plans developed in the CePaCT LTG Business Plan (CePaCT, 2023) on improving the efficiencies of CePaCT operations and long-term conservation strategies. CePaCT commits itself to improving the planning and monitoring of its budget, and to recruiting support staff to support its operational activities. It also invests in

cryopreservation (see section 2.4 above) to secure the long-term conservation of the current *in-vitro* collection for its yam, aroid, and coconut, which will greatly improve the efficiency and costs for the long-term conservation of these collections. CePaCT is doing its best to improve its genebank procedures by addressing in a planned manner the implementation of the different elements of the QMS (see sections 3.1.1 and 3.1.2 above). The reviewers feel that as the different elements of QMS are implemented, the efficiency of the genebank operations will greatly improve. More specifically, it is felt that greater efficiencies can be obtained in both the seed bank and *in vitro* collection if the processes for handling the genebank accessions can be improved in line with the recommendations provided in section 2 above. For example, in the seed bank, there is a need to reorganize the seed laboratory for the different stages of seed processing.

Our recommendation for improving efficiency is for CePaCT to continue implementing the elements of the QMS and implementing the recommendations suggested in section 2 to improve their genebank operations.

3.2 Effective enabling environment

3.2.1 Finances

CePaCT program finance is operated through SPC Fiji bank account. Financial transactions are done through a dedicated 'Job Card number' system created under SPC account and two main online financial tools for procurement Navision) and project /program financial management (ProgNav) that helps with documentation and management of all financial transactions, accessible by only program and project managers as well as financial officers. CePaCT has a dedicated staff for handling finance and is supervised by LRD Finance and admin manager. CePaCT adheres to SPC's finance policy and operates on a Full Cost Recovery (FCR) to charge out SPC's various internal services and charges 15% on expenses for Project and Program funds. SPC has procedures in place for PMF and FCR which are available on the internal SPC intranet accessible to staff only.

As the self-assessment report states, CePaCT derives around €200,000 to €300,000 per year from SPC's core funding. Eighty percent of this budget supports 3 core staff of the CePaCT genebank (Program Leader, CePaCT Curator, and the Germplasm Health Associate Scientist), and the rest provides resources for general office activities (supplies and travel for strategic events). CePaCT also receives around US$ 50,000 – US$63,000 per year as part of a Long-Term Agreement with the Crop Trust to maintain and distribute the *ex situ* collection of Pacific Regional Germplasm (aroid collection) held in trust by SPC. This funding supports 2 staff positions and covers the cost of laboratory consumables, transfer of materials for distribution, and internal capacity-building activities. CePaCT has also received project funding from the ITPGRFA Benefit sharing fund and research-focused projects from Australian Centre for International Research (ACIAR).

More recently, CePaCT obtained significant direct funding support (Aus$2.3 million) from the Australian government direct grant through DFAT for 4 years, 2019-2023. This project will end in December 2023, but it is likely that additional support from Australia will continue. In addition, CePaCT has received AUS$ 2 million for coconut genetic resources and plan health works from ACIAR Coconut for Livelihood Project. The resources from these projects have helped to support 14 staff and implement improvements such as facilities upgrade (seed laboratory, greenhouse, cryopreservation lab), barcoding and Grin Global system and sourcing key equipment.

The Government of New Zealand, through its Ministry of Foreign Affairs (MFAT), has committed to fund CePaCT for a NZ$5 million project over 5 years from 2023 – 2027. To support 12 new staff and existing positions and collecting, evaluation and characterization activities in selected SPC member countries. Also, indirect funds are available through Pacific Seeds for Life (PS4L) to support staff and to strengthen national seed system work linking to CePaCT work in 6 Pacific countries.

CePaCT representatives state that they face challenges in securing long-term funding for key staff and operation costs for meeting its objectives. CePaCT is already enjoying an LTG from the Crop Trust to cover its essential operating and a few staff cost. The Crop Trust is committed to sustaining this and is working with CePaCT to turn the LTG into a Long-Term Partnership Agreement (LPA) that would provide funding in perpetuity for its core genebank activities, subject to CePaCT meeting all its key performance indicators. Further, two potential donors (Australia and New Zealand) will further complement funding to CePaCT to enable CePaCT to meet it objectives in supporting its beneficiaries.

3.2.2 Policy

CePaCT was established in 1998 by SPC on the recommendation of the Pacific Heads of Agriculture and Forestry Meeting (PHOAFS) to 'put in place policies to conserve, protect, and best utilize plant genetic resources in countries and through regional cooperation'. In line with SPC and LRD business plan, CePaCT has set itself its objective 'to assist Pacific Island Countries and Territories (PICTs) to sustainably conserve and utilize their plant genetic resources as well as acquiring new crop diversity to address food and nutritional security, for improved resilience to climate change and pest and disease inclusion and enhanced livelihood'. Thus, CePaCT has a key role in the conservation and use of PGR in the region and is regarded by SPC as a center of excellence for the Pacific community in this area. To achieve its objectives, CePaCT developed a 10-year investment program (2018-2029) with an initial implementation phase (2019-2023). Further CePaCT coordinates the Pacific Agricultural Plant Genetic Resources Network (PAPGREN) - a regional network of national focal points from the Ministries and Departments of Agriculture in the Pacific and provides relevant policy advice to the PHOAFS on matters relating to the conservation and use of PGR in the Pacific. PAPGREN offer a formidable platform to support activities of CePaCT. Unfortunately, due to lack of funding, it has not been very active which diminish CePaCT capacity to serve the region. It is recommended that every effort should be pursued to strengthen PAPGREN to allow CePaCT to continue to play its role as a regional convenor of the network and influence policies on the conservation and use of PGR. This will also allow a greater linkage of the whole region to the ITPGRFA and global system on PGRFA.

At the global level, SPC signed an agreement in 2009 with the Governing Body of the ITPGRFA placing SPC CePaCT collection of PGRFA under article 15.5 of the Treaty Multilateral System. This policy decision is important because it opens facilitated and regulated access to the Pacific Community PGRFA, enhancing their use. It also allowed SPC to be eligible for funding from the Crop Trust (as part of the funding mechanism for the Treaty) to support the conservation of *ex situ* collections held at CePaCT. In this respect, the CePaCT has benefitted since 2019 from an LTG as support from the Crop Trust to support its routine operations in *ex situ* conservation for annex 1 crops. CePaCT must make every effort to turn this agreement into a Long-Term Partnership agreement whereby it will receive long-term funding (in perpetuity), by improving its performance and meeting the key performance indicators for long-term funding support.

So far, CePaCT has not considered the CBD Nagoya Protocol on access and benefit sharing for the germplasm distribution. Given the extended mandate of CePaCT to cover forest tree species, most of which (if not all) are not covered by the ITPGRFA, it is important that CePaCT familiarizes itself with the provisions of the Nagoya protocol and understand how it relates to those of ITPGRFA. In this respect, CePaCT can play a key regional role in strengthening in capacities of its member states in understanding the provisions between the Nagoya Protocol and ITPGRFA MLS on access and benefit sharing and help its member states and strengthening coordination between Nagoya Protocol and Treaty focal points in the region and develop a regional policy on the matter.

Recommendation 14: Continue efforts to engage in regional initiatives, in particular with PAPGREN and other regional and global initiatives such as ITPGRFA, CBD and FAO Commission on Genetic Resources for food and agriculture.

3.2.3 Staff management and succession planning

Currently, CePaCT has 24 staff organized as shown in Figure 1. CePaCT is led by the program leader on genetic resources who reports directly to the LRD director. The program leader is assisted by an admin and finance assistant for general administration and with the program's financial management. Three senior staff include a genebank curator, associate scientist-germplasm health, documentation, and database technician who oversees the work in the genebank and GHU. In addition, there are two new senior positions - the seed systems specialist, and the associate scientist – coconut genetic resources, recruited from 2020 to support the divisional focus on developing and coordinating integrated programs on seed systems and coconuts linking to the work of LRD (CePaCT, 2023). Most of the staff are key technicians who carry out the work in the genebank.

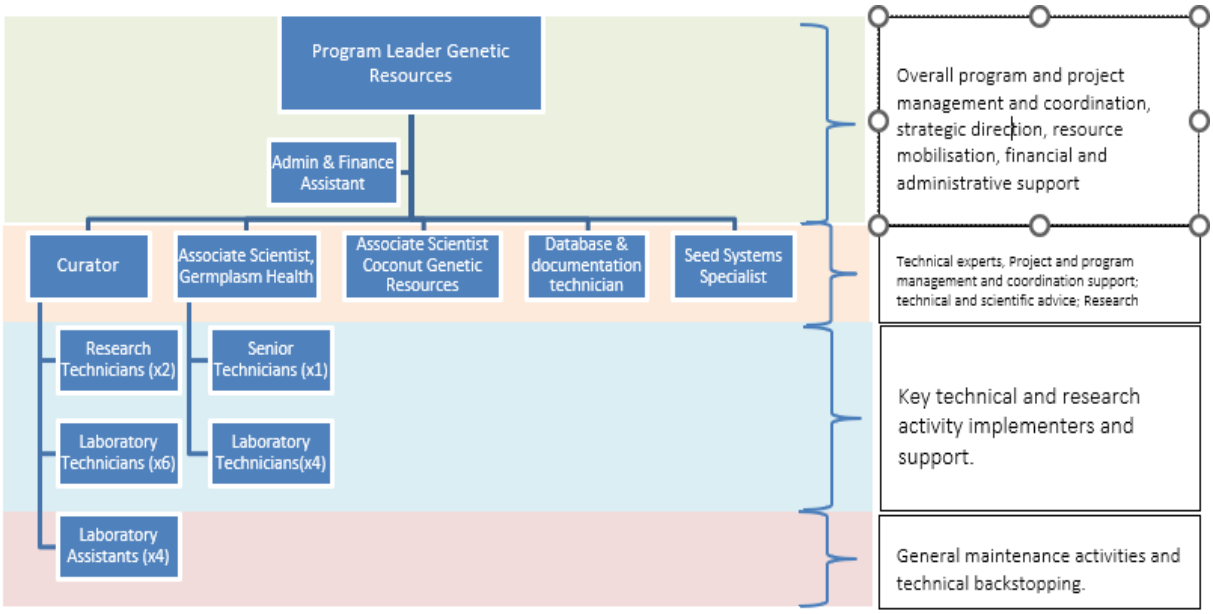

Figure 3: Hierarchical structure of CePaCT (from LTG Business plan, 2023).

Of the 24 staff, only five are on secured long term funding through SPC core funding and two staff on Crop Trust Long Term Grant Agreement, as was mentioned above in section 3.2.1). The rest of the staff are funded on short to medium term projects and grants, many of which will be ending at the end of 2023. Thus, the staffing situation is rather precarious and there is

a dire need to secure funding for the key operators of the genebank. It is good to learn that through the complementary funding from Australia and New Zealand, funding would be available to renew the contract of these key staff.

Currently, the CePaCT is faced with an immediate problem of the current curator leaving the organization and CePaCT is actively seeking a replacement. Obviously, this is a key position which must be filled at the earliest. The current curator has done an excellent job and it would be important to ensure that there would be enough handing over to the new curator before he leaves at the end of July, thus the necessity to accelerate the recruitment process.

We note that the seed bank is critically in need of staff as it has only one forest technician doing all the work now, and at least one additional technician should be posted in the genebank, particularly as the current curator will be leaving to help get the seedbank fully functional.

For the *in vitro* genebank, staffing is not the major issue, but considering the increase in the work with the coconut project and the recurrent requests for a large quantity of material, there will be a need to have two more staff in the laboratory. However, the future cryobank has only one staff and will also need two more people, given the importance of the cryobanking project of coconut, aroids and yam in the first instance.

The above needs in staffing and staff movement show how vulnerable CePaCT can find itself if action is not taken in time, as it may jeopardize all the good work that CePaCT has been doing over the past 5 years in strengthening its genebank operations. To mitigate the above risks, it is essential that SPC-LRD and CePaCT management develop a staff succession plan, which is currently missing. The investment plan has helped a lot in improving the capacity of CePaCT to support additional staff, and it is key that this should continue. But we are concerned that the additional staff have been devoted to new activities. We feel that CePaCT needs to be cautious in expanding to new work areas without first securing the core genebank operations. With new funds being committed by several donors, it is important that CePaCT prioritize its key positions that will ensure that the routine operations are carried out to high standards; quality should not be compromised for quantity. It should only expand to other activities should new complementary funding become available.

Recommendation 15: Develop a staff succession plan to ensure that CePaCT is not understaffed at any time to carry out essential genebank operation, which may jeopardise its operations.

3.2.4 Leadership

It was a recommendation of the previous review that a CePaCT lead position be appointed to not only to lead the genebank but also to provide leadership to develop strategic partnerships with regional and international centers and to contribute to the global objectives of the ITPGRFA. This review is pleased to see that a CePaCT Program Leader on genetic resources position has been created and Ms Logotonu Waquainabete has been appointed to this position. CePaCT is now actively participating in the ITPGRFA Governing body and engaging with partners in the region within the PAPGREN network. CePaCT must play a key leadership role in the PAPGREN network as it serves CEPACT's mandated countries.

3.3 Contribution to the global system of crop diversity conservation

3.3.1 User engagement

CePaCT LTG business plan (2023) identifies several key strategies for enhancing the use of its collections including developing an online tool (website) for users, defining access pathways,

user engagement through the PAPGREN network and PS4L integrated program, facilitating germplasm exchange between countries by addressing biosecurity and quarantine issues, promotion of germplasm subsets and awareness raising. The review endorses these strategies and considers that engaging with users, especially in the region, so that the germplasm conserved in CePaCT genebank is effectively utilized is critically important for CePaCT to achieve its objectives and its mission to sustainably conserve and utilize their plant genetic resources to address food and nutritional security, for improved resilience to climate change and pest and disease incursions, and enhanced livelihoods in the Pacific region.

Among the planned strategies, the LRD project Pacific Seeds for Life (PS4L) integrated program, with the coordinator sitting in CePaCT, offers the greatest opportunity for CePaCT to link directly to its ultimate beneficiaries, Pacific farmers, and work with each other mutually. CePaCT has much to offer s for the different activities of the PS4L within its three components in terms of seed conservation and germplasm health expertise and, access to locally adapted varieties, policy support, while PS4L can provide the space and partnership to promote CePaCT collection among farmers and help in participatory characterization and evaluation as well as bulking up seeds and planting materials for distribution, which are present challenges for CePaCT.

3.3.2 Partnership with national genebanks and stakeholders

From an operational viewpoint, the most important partners for CePaCT are the government SPC member countries' focal points, to which they are accountable through the PHOAFS platform and PAPGREN network. Through PAPGREN, CePaCT can plan and organize their activities for a new collection, provide technical assistance to member countries in establishing their national collection, strengthen capacity through training workshops, and ensure backup in the CePaCT collection as well as restore and send materials back to the countries. This review wishes to reiterate the importance of supporting the PAPGREN network, as it is one of the few active PGR networks globally and is part of the global system on PGRFA. It is thus very important that CePaCT continue to strengthen the PAPGREN network and actively seeks funding to help sustain the network, not only for holding meetings but, more importantly, to leverage and support the member states to participate in PGR activities regionally that help to conserve, characterize, regenerate, safely duplicate and distribute its accessions to potential uses within the region and beyond.

CePaCT has an essential role in securing the diversity of PGRFA in the region, and thus, securing partnerships with PAPGREN members and other centers in the region and internationally is key to ensuring the safety duplication of its own collection and that of its member states. CePaCT is also well placed to raise awareness about the importance of its collection and its value to stakeholders, including policymakers, breeders, researchers, and farmers in the region, to garner support and promote their use. This review acknowledges the efforts that CePaCT has been playing in strengthening its partnership with its stakeholders in the region, including research institutions, universities, NGOs, community groups, and the private sector, as well as other technical and development partners on all levels, including the ACIAR, EU, ITPGRFA, the Crop Trust and the CGIAR among others.

3.3.3 Germplasm Availability in MLS

As mentioned in section 3.2.2 (Policy), SPC has signed an agreement with the Governing body of the ITPGRFA to place its Annex 1 collection under article 15.5 of the MLS of the treaty. To this effect, CePaCT provides a biennial report to the ITPGRFA secretariat on the number of materials distributed and the number of Standard Material Transfer Agreements (SMTA) raised. As of the end of 2022, CePaCT declares that there have been about 2170 accessions

submitted to the MLS system, i.e., 99% of the *in vitro* collection. However, only 776 accessions of their collection are clean and available for distribution. CePaCT is encouraged to continue to improve its efforts to increase the number of clean accessions for distribution.

3.3.4 Contribution to the development and implementation of global crop conservation strategy(ies)

As part of its planning process, the Crop Trust has been supporting the development of crop-specific diversity conservation strategies at the global scale (i.e., Global Crop Conservation Strategies [GCCS]), as well as regional strategies covering multiple crops (Dulloo and Khoury, 2023). In 2006, a regional strategy for the *ex situ* conservation and utilization of crop diversity in the Pacific Island regions was developed by PAPGREN. SPC-LRD, through the engagement of the predecessor of CePaCT, Regional Germplasm Centre (RBG) has played a key role in the development of this regional strategy and in defining prioritization of crop diversity (aroid (taro), banana/plantain, breadfruit, sweet potato, and yam) and PGR collection in the Pacific region that forms the work of CePaCT. Today. CePaCT continued to contribute to many of the crop-specific networks such as COGENT and BAPNET and contributed to the development of crop-specific conservation strategies such as sweetpotato with CIP, yams, and banana, given that this region is endowed with unique varieties of these priority crops and considered as the center of origin for many crops.

3.3.5 Next generation conservation

With the advances in the development of new technology, genomics, informatics and digital tools, new opportunities will be available to improve how genebanks are managed more cost-effectively and efficiently. CePaCT is well positioned to innovate by adopting state-of-the-art technologies that can be useful to improve the efficiency of its genebank operations. Some key innovations that can be foreseen include the following:

- CePaCT's objective to establish a new cryopreservation facility provides an opportunity to incorporate the use of green technologies, solar renewable technologies, and other energy-saving designs. For example, using glass building blocks in some parts (upper part) of the external wall and the "skylight system" to illuminate the building's interior, provided it is well insulated. This can reduce the use of AC as it allows a temperature decrease of at least 5°C compared to the outside temperature. Further, installing solar panels and batteries can greatly reduce electricity consumption, thus increasing the CePaCT genebank's cost-efficiency.
- Consider optimizing the composition of the collections for value addition through more collaborative evaluations. Strategically, germplasm evaluation can be done in collaboration with PGR donor countries. This will allow the setting up of trait-based subsets, which is the best way to make the collection useful.
- Among the innovations in seed processing, the use of video meters are being adopted by many international genebanks such as IRRI, AfricaRice, and IITA. Using imaging technology, the video-meter tool is useful for automatically generating uniform and accurate seed identification.
- In the era of genotyping and molecular characterization, the large number of DNA materials extracted from the germplasm should always be managed to keep samples as backup. This can be structured as a DNA bank that can be used as reference material and for research purposes. Moreover, DNA materials are easier to exchange as they are not subject to stringent phytosanitary regulation, even if they still need legal agreement and should comply with policy guidelines.
- In the same logic of availing alternative germplasm material, a lyophilized leaves collection can be set up from the collection. Such material will also serve as a reference

for germplasm identification, as samples for research purposes and can be exchanged relatively easier.

- Regarding germplasm management, the CePaCT genebank can include RFID tags in setting up the online inventory and monitoring system. As an alternative to the barcoding system, this sample identification and tracking method can be considered for the cryobank, where the ultra-low temperature may be challenging for barcode labels. This radiofrequency-based technology is used in the IITA cryobank, allowing the reading of cryo-box sample composition in low-temperature conditions without the risk of label loss or scanning issues.

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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. CePaCT was reviewed by two experts, facilitated by Sarada Krishnan (Director of Programs, Crop Trust) and Luigi Guarino (Chief Scientist). The members of the review panel are:

- *Ehsan Dulloo: Chair of the review panel with experience in conducting genebank reviews with expertise in institutional analysis, diversity assessment, and genebank management.*
- *Badara Gueye member of the review panel with expertise in in vitro and cryopreservation.*

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 agenda of the visit 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*	Number of accessions (in vitro)	Number of accessions (seeds and field)
Composition		
1. Number of accessions in total	2414	92
2. Number of seed accessions		43
3. Number of accessions in *in vitro*	2414	
4. Number of accessions in cryo conservation	0	0
5. Number of field bank accessions		33
6. Number of accessions in *in vitro* and in field	6	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	0
Availability		
10. Available for immediate distribution	776	7
11. Viability tested		4
12. Viability above 85%		3
13. Health tested	1023 (indexing)	0
14. Adequate seed number	564 (low number)/2190	Y
15. Included in MLS	2170 (15 Bele, 5 Pandanus not included)	N
16. Regenerated or multiplied in last 5 years (seeds)		0
17. Samples subcultured in last 5 years (clonal)	2190x2x5=21900	
18. Samples rejuvenated in the field/greenhouse in last 5 years (clonal)	192	
Safety duplication		
19. Conserved in LTS (seeds)		7
20. Safety duplicated outside the genebank (first level, seeds)	20 (10 IITA, 10 ITC)	0
21. Safety duplicated at two locations (two levels, seeds)		0
22. Safety duplicated at Svalbard (seeds)		0
23. Field collection maintained in at least two locations		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	20 (10 IITA, 10 ITC)	
26. Number of field bank accessions held, also in *in vitro* and in cryo[but not in cryo]	0	6
Distribution		
27. Total distributed internally in last 5 years (within the institute)	156 accessions/2702 samples	0
28. Total distributed nationally in last 5 years (outside the institute)	145 accessions /1771 samples	143
29. Total distributed internationally in last 5 years	0	500
30. Number of countries receiving germplasm in last 5 years	16 (13 out of the 22 SPC)	
Information		
31. With passport data available in Genesys		
32. With characterization data available in Genesys		
33. Average passport data completeness index		4.96
QMS		
34. Number of SOPs written	3	3
35. Number of SOPs reviewed and approved	0	0
36. Staff succession/management plan available and maintained (Y/N)	N	N
37. Risk management plan available and maintained (Y/N)	Y	N
38. Equipment and supplies inventory available and maintained (Y/N)	Y	Y
Use		
39. Number of germplasm requests received annually (average last 5 years)		325
40. Regular feedback from genebank users (Y/N)	Y	Y

* Consider crop disaggregation where relevant.

Annex 3 Review checklist

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

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

Area	Factors to consider	*Score
Overall assessment	29. Provide an overall assessment of the adequacy of genebank supplies, equipment, facilities & infrastructure.	0
B. Genebank operations		
Area	**Factors to consider**	
1-Acquisition		
1 Adequacy of procedures	30. The genebank assesses viability and phytosanitary health upon reception of new material.	0
	31. The genebank has post-entry quarantine rules for new materials, prior to introduction into the genebank collection.	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.	0
	33. Data and information generated during the acquisition procedure are recorded and entered into the documentation system in a timely manner.	2
3 SOP	34. The genebank has a written acquisition procedure/protocol/policy.	3
Overall assessment	35. Provide an overall assessment of the adequacy of the procedure.	2
2-Conservation: seed processing, storage, and viability testing		
1 Adequacy of procedures	36. The genebank follows an established protocol for seed cleaning.	1
	37. The genebank follows an established protocol for seed drying and testing of moisture content.	1
	38. The genebank follows an established protocol for packing samples in containers or envelopes.	1
	39. The genebank periodically conducts viability testing.	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.	0
2 Information management	41. Samples are properly labeled.	1
	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
3 SOP	43. The genebank has a written conservation procedure/protocol/policy.	1
KPI: Viability and health testing rates	44. The genebank has information on the viability/vigor and health of the collection.	2
Overall assessment	45. Provide an overall assessment of the adequacy of the procedure.	1
3-Field genebank		
1 Adequacy of procedures	46. The genebank follows an established protocol for field conservation and regularly monitors the quality of plants.	2
2 Information management	47. Samples are properly labeled.	1
	48. Data and information required for and generated in field genebank are recorded and entered into the documentation system in a timely manner.	2
3 SOP	49. The genebank has a written field genebank conservation procedure/protocol/policy.	2
Overall assessment	50. Provide an overall assessment of the adequacy of the procedure.	2
4-In vitro conservation		
1 Adequacy of procedures	51. Light and temperature regimes are adequate for in vitro culture	2
	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	0
2 Information management	53. Samples are properly labelled.	1
	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.	2
3 SOP	55. The genebank has a written in vitro conservation procedure/protocol/policy.	1
Overall assessment	56. Provide an overall assessment of the adequacy of the procedure.	2
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
	58. Environmental parameters (e.g., photoperiod and vernalization requirements) of field sites are appropriate for the needs of the target crop(s)	2

Area	Factors to consider	*Score
	59. Field management activities (land preparation, irrigation, rouging, agrochemical applications) are adequate for regeneration and characterization of genebank accessions	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 Information management	61. Characterization data is publicly available, or available upon request.	0
	62. Samples are properly labeled.	1
	63. Data and information required for and generated during regeneration and characterization are recorded and entered into the documentation system in a timely manner.	2
3 SOP	64. The genebank has a written regeneration and characterization procedure/protocol/policy.	3
KPI: Regeneration & characterization rates	65. The genebank has information on the number of samples regenerated and characterized annually.	1
Overall assessment	66. Provide an overall assessment of the adequacy of the procedure.	2
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.	0
	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.)	0
	69. Samples are distributed in compliance with national laws and relevant international treaties and conventions.	0
2 Information management	70. Samples are properly labeled.	1
	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.	2
	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.	1
3 SOP	73. The genebank has a written distribution procedure/protocol/policy.	1
KPI: Distribution	74. The genebank has information/trends on the distribution of its accessions.	0
KPI: User satisfaction	75. The genebank requests feedback from users to improve the delivery of genebank service.	0
Overall assessment	76. Provide an overall assessment of the adequacy of the procedure.	1
6-Safety duplication		
1 Adequacy of procedures	77. Safety duplicate samples are stored nationally, under the same or better conditions than those in the original genebank.	3
	78. Safety duplicate samples are stored internationally, for second-level safety duplication.	3
	79. The size of safety duplicated samples is sufficient to conduct at least three regenerations.	3
2 Information management	80. Samples are properly labeled.	n/a
	81. Data and information required for and generated during safety duplication are recorded and entered into the documentation system in a timely manner.	n/a
3 SOP	82. The genebank has a written safety duplication procedure/protocol.	n/a
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.	3
Overall assessment	84. Provide an overall assessment of the adequacy of the procedure.	3
C. Genebank management		
Area	**Factors to consider**	*Score
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
Information management	86. Information management system is available and used in the management and monitoring of the collection.	3
	87. Passport and accession-management data are secured by regular data backups.	0
	88. Passport and other relevant data are available and accessible to external users.	2
Germplasm health	89. The genebank (or its health unit) maintains and updates a list of quarantine pests and diseases.	0
	90. Phytosanitary procedures are followed in germplasm transfers (import and export).	0

Area	Factors to consider	*Score
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).	0
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
Overall capacity	93. The genebank's overall capacity to conserve seeds, clonal crops, and field collections is adequate	1
D. Institutional areas		
Area	**Factors to consider**	*Score
Finance	94. The institution has a clear policy on overhead charges on projects and/or international collaborations.	0
Procurement processes	95. The institution has an established procurement process.	0
Genebank routine funding	96. The genebank has reliable and continuous funding sources for routine operations (e.g., core vs project funding).	0
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
Leadership	98. The genebank has clear leadership, commitment, and vision for improving genebank operations and management.	0
Use	99. The genebank works with farmers and other user groups to promote awareness and use of materials from the genebank.	1
Contribution to the global system	100. The genebank works with national genebanks and other partners on crop conservation-related activities.	0