

CIAT Genebank Review 2019

Programme: Genebank Platform				
Genebank reviewed: CIAT		Site visit dates: 2-6 December 2019		
		Review report date: 20 January 2020		
		Center and Crop Trust responses: 13 May 2020		
Place: Palmira, El Carrizal and Corrales, Colombia				
Genebank Manager		Peter Wenzl		
Review Panel		Theo van Hintum		
		Marisé Borja		
Crop Trust staff		Janny van Beem		
	Observation	Recommendation for clearance	Due date	Responses
1	1 Major observation	Strengthen in vitro-team with experienced staff, including hiring an experienced tissue culture manager, who are able to tackle immediately the specific challenges the cassava collection faces.	Plans due by end of March 2020 Team strengthened by end of June 2020	<u>CIAT:</u> We agree and have already hired an additional Research Assistant to compensate for the ongoing medical leave of the former In-Vitro Coordinator since Q1-2019. Hiring a more experienced, internationally recruited <i>Tissue Culture Manager</i> would require additional funds; so, we are unsure if/when such a recruitment will be possible. Hiring additional technicians will only be feasible after moving to the new genebank building because the current facility is too small to accommodate more staff. <u>Crop Trust:</u> Agrees with recommendation and appreciates CIAT's rapid response. Clearly a longer-term solution is required here. The move and hopefully the System level review will help here.
2	1 Major observation	Genebank manager's terms of reference should be re-evaluated with the aim of ensuring more time is dedicated to the management of the collections or, if not, specific tasks are delegated to qualified staff.	Decision due by end of June 2020	<u>CIAT:</u> The Alliance has contacted ILRI to remove the clause from our MoU which outlines our Genebank Manager's supervisory role vis-à-vis the ILRI Genebank Manager. In order to ensure that our new genebank is fit for purpose, however, it is important that the Genebank Manager is available (a) to participate in the committee overseeing the construction process, and (b) to coordinate the transfer of the collections and equipment to the new building. Once completed, his role will exclusively focus on the <i>ex situ</i> conservation of germplasm collections. <u>Crop Trust:</u> We can appreciate both recommendation and response here. It seems that CIAT faces a difficult period whereby the collections are in need of critical attention and oversight while other external priorities clearly must be addressed too. When operations are running smoothly it should be expected that an IRS genebank manager is involved in research and other activities. So, from Crop Trust perspective, we consider that this extra vigilance is required as a temporary measure until the tissue culture collection and other

				issues are resolved. It is good to see that some response has been possible. However, it is unlikely that CIAT's contribution to developing closer alignment in management of the CIAT and ILRI Tropical Forages collections will diminish even though the formal MoU is withdrawn. It may be important to consider delegating further duties if necessary and we hope that during this period, CIAT senior management and colleagues provide support also to the genebank manager in this respect.
3	1 Major observation	Seek legal counsel regarding the interpretation of the law regarding enforced retirement of female staff at 57 yrs (Art. 33 and 36) and determine if skilled female staff over this age can continue to be employed or re-employed.	Determine possibilities by end of 2020	<p><u>CIAT:</u> The Alliance's Legal Office is going to seek independent legal advice to explore options for (re)employing skilled female staff who are over 57 years old.</p> <p><u>Crop Trust:</u> Agrees with recommendation and response.</p>
4	1 Major observation	Bean and forages data should be migrated to GRIN-Global and all inventory management implemented from one database (GRIN-Global).	Inventory management for all crops implemented from GRIN-Global by end 2020	<p><u>CIAT:</u> We agree and have already been working on this task for some time. The issue here is that "data migration" is just the tip of the iceberg. The far more time-consuming tasks are: (a) recovering, standardizing and curating historical inventory data from multiple legacy databases; (b) the development of a data model that accurately reflects current genebank workflows; (c) re-packaging, seed-counting and re-barcoding of approx. 290,000 seed pouches stored at -18C; and (d) the redevelopment of >10 mobile apps for data capture and barcode reading/printing which synchronize with our legacy databases and are incompatible with GRIN-Global. Depending on the duration and degree of the COVID-19 lockdown, we may be able to migrate the bean collection until Dec 2020, with the forage collection to be tackled starting in early 2021.</p> <p><u>Crop Trust:</u> The reviewers express a sense of urgency. CIAT's response clearly indicates the recommendation is in hand but that there are levels of complexity to deal with. We are delighted that the desired outcome is possible before the end of the Genebank Platform although with a delay with respect to the reviewers suggested deadline.</p>
5	2 Major observations	Software scripts and tools should be developed to allow regular overview of the status of the collection and prioritization of accessions for viability testing, regeneration, safety duplication, etc.	End of 2020	<p><u>CIAT:</u> Agreed; this is essentially a follow-on aspect of Observation 4 and the reason why we need to develop a data model that accurately reflects current genebank workflows (which does not exist in our legacy databases). Once curated inventory data has been migrated to a GRIN-Global instance configured according to our new data model, a number of SQL queries can be developed by Q1-2021 to support the management of the seed collections.</p> <p><u>Crop Trust:</u> Agrees and pleased with the response although some delay from suggested deadline.</p>
6	1 Minor observation	The number of accessions reaching acceptable thresholds and % physical and legal availability for the entire collection should be updated, validated and reported to Crop Trust and Genesys (see also Recommendation 15).	As soon as possible. Report when completed.	<p><u>CIAT:</u> We agree and have already implemented these measures. The number and % of accessions that are available for distribution are being regularly updated in Genesys and are also reported on an annual basis in the ORT (see our most recent report with a cut-off date of Dec 2019 in the ORT). All accessions registered in Genesys form part of the MLS of the ITPGRFA and hence are legally available. Seed accessions classified as physically "available for distribution" have sufficient numbers of seeds with above-threshold viability levels and have been tested and confirmed to be free of >40 quarantinable pathogens. <i>In vitro</i> cassava accessions are classified as "available for distribution" if confirmed</p>

				<p>to be free of 7 quarantinable viral and phytoplasma pathogens.</p> <p><u>Crop Trust:</u> Agrees with the recommendation and the response. A successful outcome to Rec. 5 will be an essential element to make this reporting and validation easier in the future.</p>
7	1 Major and 1 minor observation	Review and improve the viability monitoring process to ensure viability thresholds are not missed without triggering a regeneration while also avoiding unnecessary tests and addressing the backlog.	New viability testing SOP by end 2021	<p><u>CIAT:</u> Agreed. In Jan 2019, we implemented a more efficient sequential-testing procedure for bean viability-monitoring, which has not yet been fully described in the SOP and was not reviewed. The procedure has increased our viability-monitoring throughput by 33% in 2019 (see ORT report). It seems unlikely that we are missing low-viability accessions, given our overly conservative (too frequent) testing intervals, which have created backlogs in some areas. (Concerns about missing viability thresholds may have arisen because of some poorly germinating bean-regeneration plots that had been planted with historical MOS; given the few seeds typically left, these MOS were not viability tested before planting.) Once global analyses of viability data have been completed for the two seed collections, test intervals will be adjusted to avoid unnecessary tests.</p> <p><u>Crop Trust:</u> Agrees with the recommendation and response. We appreciate the detail provided here and CIAT's role in leading a workgroup on seed quality management. It seems there are practices and improvements here that might benefit the wider group.</p>
8	1 Minor observation	Increase options used to break dormancy by working with partners and trying out new protocols for all wild accessions, particularly in the forages collection.	New viability testing SOP by end of 2021	<p><u>CIAT:</u> Although tedious, the mechanical-scarification protocol we are using for all forage legumes and beans actually works very well across a broad range of 700+ species: we only reject 3-4% of regenerated accessions (this was perhaps not discussed during the review). For a few forage legumes such as <i>Stylosanthes</i> and <i>Desmodium</i>, we have developed heat-treatment protocols to save time. Dormancy in forage grasses, however, is a bottleneck and currently forces us to use tetrazolium instead of germination-testing. It appears there will be funds for a project targeting this topic in 2021/22.</p> <p><u>Crop Trust:</u> Important recommendation and clearly not new to CIAT. I think that the project referred to is 2020/21 and indeed looking forward to see CIAT's leadership here.</p>
9	1 Major observation & 3 minor observations	Data gathering and management in the field should be improved so that pest and disease incidence is recorded in the database and the number of descriptors used are increased and used for identity confirmation against designated reference samples.	Data gathering improved by end of 2020	<p><u>CIAT:</u> Agreed; this is another aspect of Observation 4 because investing in incorporating these features into our current legacy databases would delay migration to GRIN-Global. Instead, we will add these functionalities into the new data model to be used for configuring GRIN-Global. The mobile apps for data-gathering and barcode reading/printing, which have to be re-developed to connect to GRIN-Global, will include functionalities for identity confirmation and recording disease incidence in the field. These features, therefore, will become available at the same time as the GRIN-Global-based inventory management system is deployed for the bean, and subsequently, the forage collection.</p> <p><u>Crop Trust:</u> Agree with both recommendation and response.</p>
10	1 Minor observation	Measures should be taken to increase regeneration success rate in terms of sufficient healthy seed	Piloting of new approaches in	<p><u>CIAT:</u> Over the last several years, we have already taken a range of measures to improve regeneration efficiencies (see previous ORT reports). Two key</p>

		harvested in one regeneration cycle, especially in the forages collection.	place by end of 2020.	<p>intervention points, however, remain to be tackled: (a) increase the number of bean seeds harvested by expanding plot sizes in screenhouses by approximately 70% and (b) regenerate forage accessions under plastic roofs to reduce the incidence of fungal diseases. Both measures should increase regeneration efficiencies but will also substantially reduce the number of accessions that can be regenerated per year. We will start implementing these measures when re-vamping regeneration work after the partial COVID-19 lockdown. However, it is important to keep in mind that we are now regenerating the most difficult accessions, many of which have already been attempted to be regenerated, sometimes several times. So, biological limitations, such as disease susceptibilities and a lack of adaptation to available regeneration sites (elevation, soil), will likely put a limit on regeneration efficiencies over the next several years.</p> <p><u>Crop Trust:</u> Important recommendation and we are aware of progress that has been made over the years, especially on the bean regeneration. We appreciate the response and look forward to hearing further reports on progress.</p>
11	2 Major & 1 minor observations	Control samples should be designated for all three crop collections so environmental variation between different fields and different years can be corrected for from now on.	Reference samples known by end of 2021	<p><u>CIAT:</u> Agreed, except for the cassava collection, which has not been grown in the field for decades. As we re-configure the spatial layout of bean and forage regeneration plots (see Observations 10 and 12), we will identify suitable 'control accessions' and attempt to seek input from a biometrician to optimize the design and spatial layout in screenhouses and open-air regeneration fields.</p> <p><u>Crop Trust:</u> Agrees</p>
12	1 Major observation	Improve forage collection management using recent studies regarding CIAT/ILRI forage collections and potential liaison with ICARDA regarding pollination control and develop and implement strategy for rationalizing the collection and improving conservation activities.	Revised SOPs and rationalized collection by end of 2021	<p><u>CIAT:</u> We agree. As previously reported in the ORT, we have already developed and (internally) implemented a strategy for rationalizing CIAT's forage collection during 2018/19. Accessions will be publicly earmarked as "archived" in Genesys, once Genesys has a functionality to do so and the "Accession Management" White Paper has been approved by the DGs of A15 CGIAR centers. Improved pollination-control measures (greater spatial separation, screenhouses, single-accession isolation cages with natural pollinators, etc.) will be tested, optimized and adopted when re-vamping regeneration work after the partial COVID-19 lockdown.</p> <p><u>Crop Trust:</u> Agrees with the recommendation and has appreciated CIAT's concrete actions on the CIAT/ILRI study. We look forward to hearing reports of the pollination-control measures. It is past time that a community of practice was set up on conservation of wild species and maybe controlled pollination crops could be included here too.</p>
13	1 Major observation	Improve the online experience and access to varied data, especially characterisation data, to promote and facilitate use of diversity, including improving the prominence of the genebank web site on CIAT's website.	Strategy to be developed in 6 months and implemented by end of 2021.	<p><u>CIAT:</u> We agree, but also need to work within the limitations of existing databases and institutional website-design priorities. We have stopped improving the functionalities of our current Oracle-based web portal since institutional support for this platform is scheduled to be phased out in 2020 and we are migrating our transactional databases from Oracle to GRIN-Global. Given the obligation to continuously update Genesys, we will adopt Genesys as our genebank's web portal for the time being. Genesys functionalities for filtering accessions based on characterization data, however, are limited. Because of the recent Bioversity-CIAT</p>

				<p>merger, the institutional website will be completely revamped, and we will strive to enhance the visibility of the genebank pages in the process.</p> <p><u>Crop Trust:</u> Indeed this is a recommendation that should also be directed at Crop Trust for Genesys development.</p>
14	5 Major observations	To address the current poor health of the cassava <i>in vitro</i> collection, losses of accessions, and the old age of existing cultures, rejuvenation from the bonsai or alternative sources should be carried out with some urgency, plus increased monitoring and replacement of cultures implemented and efforts taken to understand how and why cultures are becoming infected.	Actions taken and reported to Crop Trust by June 2020. Processes revised by end 2020.	<p><u>CIAT:</u> We agree; this is an important observation. As already partly outlined in our “lost accession action plan” (see ORT reports), the historical cassava-conservation strategy requires an overhaul, including: (a) reducing the incidence of <i>in vitro</i> contamination with saprophytic or endophytic bacteria; (b) the genetic characterization of the entire collection for future trueness-to-type testing (since there is no field collection left); (c) the rejuvenation of a genetically non-redundant accession subset, followed by (d) a fresh round of virus-indexing and phytosanitation, (e) the establishment of a cryopreserved base collection using droplet vitrification of meristems, (f) the return of wild species to the field to produce materials for cryopreservation of seeds, (g) a tightening of barcode-enabled inventory-management procedures, (h) a more spacious and aseptic working environment, and (i) more (qualified) staff (as per Observation 1). We previously found that most accession losses occurred around 2011, when the collection was temporarily moved to the herbarium (see ORT reports). A tissue-culture specialist, hired as a consultant early in 2020 to perform a two-week long review to follow up on the reviewers’ observations, concluded that elevated levels of bacterial contamination (peaking around 2011 and decreasing since then) probably were one, though not the only factor for accession losses. Some wild accessions have lost the ability to produce roots and may be lost in the future since there is no field collection to go back to. Several of the elements of the above outlined strategy can only be implemented, once we have worked off the sub-culturing backlog caused by the COVID-19 lockdown and we have moved to the new genebank building with better and more spacious tissue-culture laboratories. Some of the interventions will also require additional funds.</p> <p><u>Crop Trust:</u> Important recommendation and we appreciate CIAT’s action in this regard.</p>
15	1 Major observation	Reassess availability of the cassava collection to take account only of healthy cultures and provide corrected report to Crop Trust (see also Recommendation 6).	Corrected availability data to be provided for 2019 report	<p><u>CIAT:</u> The issue here is the definition of “availability”. As outlined under Observation 6, we declare accessions that have been tested and confirmed to be free of <i>quarantinable</i> pathogens as “available for distribution”. We currently do not use contamination with saprophytic or endophytic bacteria as a criterion to declare an accession as “not available” because we pre-culture such accessions on an antibiotic-containing medium before shipment. According to Lava Kumar, coordinator of the CGIAR’s GHU network, this is a generally accepted practice. We are happy to adhere either to the currently used or a more stringent definition of “availability”. However, before deciding which definition to use, we suggest this question is discussed and decided by the GHU network to harmonize the definition of “availability” across all A15 genebanks.</p> <p><u>Crop Trust:</u> A significant recommendation and one that should be discussed within the GHU and Clonal CoPs.</p>

Introduction

Commissioned by the CGIAR Genebank Platform, a review of the CIAT Genebank was carried out by Dr. Marisé Borja, associate professor at the Universidad Complutense de Madrid and Dr. Theo van Hintum, head of the PGR department of the Centre for Genetic Resources, The Netherlands (CGN). The reviewers were supported by Janny van Beem, Genebank Quality Management System Specialist.

This review aimed to conduct an in-depth assessment of the long-term sustainability of the genebank's routine operations and their eligibility for long-term funding through the endowment mechanism. The review focused on a wide range of areas including the validation of the status of the collections and its associated information, efficiency of operations, policy compliance, staff and risk management and the center's responsiveness to users. In preparation for the visit, the reviewers received a wide spectrum of documents, including the Standard Operating Procedures (SOP) in Spanish and largely translated in English, Platform documents such as the ORT reports, a self-assessment of genebank management and the results of a user survey.

On December 2-6, 2019 the review team visited CIAT's location in Palmira, Colombia. On arrival at CIAT, the review team was welcomed by Ruben Echeverría (Director General), Joe Tohme (Agrobiodiversity Research Area Director), Peter Wenzl, (Leader-Genebank manager) and Marcela Santaella (Genebank Operations Manager), and the Germplasm Bank team leaders: Luis Guillermo Santos, Mónica Vélez, Javier Gereda, Juan José González, Maritza Cuervo, Mónica Carvajal, and the genebank's administrative assistants Josefina Martínez Realpe and Claudia Maldonado. After the introduction, a brief tour of the genebank facilities took place to get to know the genebank and the key staff, and an introduction to key processes was given by the staff responsible. The review team met again on the last day for the presentation of the preliminary findings with Joe Tohme, Maya Rajasekharan, Peter Wenzl, and Marcela Santaella.

Over four days, the review team interviewed the teams responsible for the different crops and operations, inspected facilities and processes, and met with the technical staff at their workstations. Furthermore, a day visit to the multiplication sites of El Carrizal and Corrales, c. 2 hours from Palmira and a brief visit to Future Seeds, CIAT's new genebank under construction, were organized. Most elements of the program were done by all three review team members, the visit to the -20°C vaults was only done by Dr. Borja together with Alejandro Medina and Jason García, the visit to the HR department and documentation storage sites (paper copies of introduction and distribution documentation) was done by Dr. van Beem with Josefina Martínez and Marcela Santaella.

Intense discussions were held with the heads of the eight operational genebank teams, i.e., Luis Guillermo Santos, Mónica Vélez, Javier Gereda, Juan José González, Mónica Carvajal, Juan Carlos Guerrero, Dimary Libreros, and most of the other permanent staff members of the genebank, i.e., Aida Naranjo Ramirez, Jose Wilmer Avila Triviño, Rocio Cuero Arboleda, Yefferson Hernandez Sanchez, Ramiro Sabogal Carvajal, Luis Enrique Borrero, Lilia Cuasialpud, Diana Patricia Arias, Ceneida Perenguez, Fanny Gil Ceballos, Jose Ignacio Ortiz, Maria Mercedes Parra, Nestor Campana Cuaran and Melida Diaz Martinez. The eighth operation group, the GHU, is led by Maritza Cuervo who gave a tour of the laboratory. Julio Cesar Ramirez Pretelt, also from GHU, accompanied the Review Team to regeneration fields at the Carrizal station.

Part audit of SOPs and part technical assessment, this type of review is relatively new to the Platform. Since both reviewers had already reviewed two genebanks with this new mandate this caused no problems. The team was able to readily obtain answers, documents or other evidence from the genebank staff without delay or hesitation. This culture of transparency is an essential step towards proper quality management. The reviewers gratefully acknowledge the cooperation and patience of the CIAT genebank staff throughout the review.

The audit of the SOPs and the reviewers' assessments of processes in need of improvement are detailed in the attached Review Checklist. There are 15 recommendations, related to 14 major observations and 13 minor ones. The overall findings were presented to CIAT

management and the genebank's staff on the final day, to avoid factual mistakes and receive initial feedback. It was agreed that all recommendations could be tackled; several were already known to Management and a strategic plan to address them as was presented by Peter Wenzl on the first day of the review.

General remarks

Peter Wenzl referred to the genebank review as a mirror, to see activities to be proud of as well as areas to be improved.

The CIAT genebank contains an invaluable wealth of genetic resources of beans, cassava and tropical forages, and has received the global mandate to safeguard these genetic resources and make them available for current and future generations. The genebank is located in a perfect scientific environment with expertise in all aspects of the crops, and with a good connection to various user communities. Overall the genebank is well organized and it is relevant to highlight the dedicated enthusiasm shown by every staff member who work as a true team with constant efficient interactions among the different departments. Team leaders have recently been given additional independence regarding budgets and other aspects resulting in a positive increase of responsibility and responsiveness.

Like any other genebank, many small issues can and should be improved, and suggestions can be made to make the operation more effective. At the CIAT genebank, however, the review team observed a few major problems, especially in the cassava *in vitro* collection, that require immediate action. These were related to the fact that a significant proportion of wild cassava accessions as well as a few cultivated accessions have been lost in the last twenty years. The CIAT genebank has addressed the infection of frogskin disease in the cassava *in vitro* collection resulting in a decrease in infected accessions from approximately 1,500 (25% of the collection) in 2017 to less than 500 in 2019. The team can only hope that the loss of accessions in this collection will be prevented through similar assertive preemptive measures.

The CIAT genebank is a very impressive operation, with an important future planned in the new iconic facility of Future Seeds, which we sincerely hope will be a worldwide showcase for genetic resources conservation. Thanks to the coordination of reviews by the Trust, and especially the quality management component therein, the important shortcomings are now being identified and addressed with the objective of bringing the genebank operation up to excellent standards, and ultimately to perfection. The results of this review should be seen in this light; steps toward improvement that would ultimately lead to a secure and future-proof genebank.

Overview of recommendations

Details of observations, recommendations, and proposed actions are given in the attached Review Checklist, the text below offers a broad overview of the recommendations and suggestions on how to address them. The numbering corresponds to that in the Review Checklist.

The review team observed many very positive elements in the genebank program. Clear examples are the phytosanitary monitoring, which recently received ICA certification, only one of two currently existing in Colombia; the crop field management; the seed identity validation after harvest with a high number of accession pod and seed pictures available on-line, the extensive use of barcode readers and tablets, the nano-propagated cassava tubes as backup, the intensive care units for difficult accessions, and the training activities for genebank staff.

The list of improvements starts with observations related to staff workload: On the one hand, the *in vitro* team is not strong enough (both in terms of experience and number of people) which is particularly relevant given the current situation of the cassava collection. On the other hand, the genebank manager is overloaded with other tasks such as construction design, fund-raising or oversight of genebanks other than CIAT: The recommendation is straight-forward: Strengthen the *in vitro* team with an experienced scientist at manager level who can

immediately tackle the multiple challenges the cassava collection faces (Recommendation 1). Furthermore, regarding staff management, it is necessary to re-evaluate the current responsibilities of the genebank manager to allow him to give full attention to genebank management (Recommendation 2).

The second finding regarding staff (Recommendation 3), is the apparent forced retirement of highly experienced females at 57 years due to CIAT's interpretation of articles 33 and 36 ("Requisitos para obtener la pension de vejez" and "Regimen de Transición) of the Colombian law 100. Mandatory retirement such as this is seen as a waste of capacity in terms of losing productive years of scientific knowledge, especially given that gender equality is one of CGIAR's guiding principles. For this finding, the action is also clear-cut seek external legal counsel regarding interpretation of the law and communicate the results to CIAT management to determine if there is a way to deal with this restriction on keeping important staff members (Recommendation 3). Additional minor findings suggest the need to implement competency testing for all staff.

While abundant data are recorded at different time points, these data are stored in multiple unconnected databases, so meta-analysis for collection management is almost an impossible task, except for the cassava collection, which has been migrated to GRIN-Global. Data management issues start with the lack of a Data Management SOP, although the most urgent matter is the need to organize and migrate bean and forage data to GRIN-Global as soon as possible (Recommendation 4). Once the migration to GRIN-Global has been implemented, germination and availability data should be re-validated. On the legal side, the review team observed that even though there is an ongoing effort to find and digitalize all historical documents related to individual accessions in the collection, the documentation is not complete yet. Validating the physical and legal status of the accessions is a critical need for genebank management and reporting and involves both the recording of necessary information per accession and being able to manage it in a single data management system to produce accurate reports (Recommendation 6). The same system should have the capacity to automatically select material for regeneration according to viability and seed availability data per accession and be generally queried to get reproducible results (Recommendation 5).

When the review team assessed the viability tests, they found that there was a 3-year backlog and that few dormancy breaking protocols are in place, especially when compared to other Centers working with forages (e.g. ICARDA or ILRI). A research project on breaking dormancy is under way with these Centers under the supervision of Fiona Hay. CIAT has also worked closely with ILRI to compare processes and the Reviewers strongly recommended that CIAT devotes some effort to identify new options for dormancy breaking (Recommendation 8). The policy for viability testing and its practical implementation needs to be reconsidered to avoid unnecessary testing while also ensuring that viability doesn't drop so low it hampers regeneration (Recommendation 7). Much work has been put into critically assessing the conservation priority of different species in the forages collection, CIAT is in the process of implementing the recommendations of the tropical forages species prioritization study and continued improvement of conservation activities and protocols surrounding the management of the forages collection is recommended (Recommendation 12).

Pest and disease evaluation of regenerated accessions is excellent. However, not all of the results are recorded in the database limiting their usefulness for accession evaluation and feeding into field management (Recommendation 9). Characterization data relies on a small number of descriptors and the link to information generated by breeders is very limited. The situation is particularly relevant in forage accessions. Furthermore, the characterization data obtained by the bean and forages regeneration and documentation teams cannot be compared to reference samples since they have not been designated so the capacity to carry out identity verification in the field is questionable (Recommendation 11). In terms of regeneration, the review team was impressed by excellent crop management practices. However, the regeneration success of bean and forage accessions has been consistently low which reflects the current planting regime and potentially low viability of seed and should be addressed (Recommendation 10). Improving the availability and use of characterization data plus highlighting the genebank's pages on CIAT's newly-renovated website will have a much-needed positive impact on the potential for use of the collection (Recommendation 13).

The overall status of the cassava *in vitro* collection is critical in terms of facilities, health and genetic integrity. There is also continued use of hand-writing together with barcodes. Under these circumstances, it is necessary to critically review and overhaul the monitoring and management of the *in vitro* collection and take action to improve the health of the cultures and control infections. It is highly recommended to implement a rejuvenation scheme for the *in vitro* cassava collection and reintroduce clean identity-verified accessions back to *in vitro*. The bonsai collection could be a good option for reintroduction once identity has been verified and phytosanitary status has been cleared (Recommendation 14).

The Future Seeds genebank facility will be wonderful and ample proactive measures are in place to safeguard staff and genetic resources. However, it is surprising that the fire alarm system in the current genebank facility has not been functional in the last 30 years although installation and testing were ongoing during the review.

The reviewers hope that these recommendations for improving the operations of the genebank will help the genebank reach the high standards that are appropriate for an operation of such immense importance.

Theo van Hintum and Marisé Borja
December 17th, 2019