CIMMYT

Genebank Review Report 2025

CROP TRUST

Global Genebank Partnership

Genebank Review Report

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1 Summary of Review Findings and Recommendations

[List the strengths of the genebank and a summary of priority recommendations presented in Table 1.]

CIMMYT is a globally recognized genebank managed by qualified and engaged curators and enthusiastic staff. The CIMMYT genebank conserves approximately 124,000 wheat and 28,000 maize accessions, including landraces, improved lines, synthetics, genetic stocks, and wild relatives. The CIMMYT genebank staff and leadership demonstrate great commitment to their work, collaborative spirit and passion. The current genebank curators, Dr. Carolina Paola Sansaloni (wheat) and Dr. Alberto Chassaigne (maize), were both hired within the past few years. Their energy and eagerness for both their crops and genebank improvements are very apparent, and as a result of their efforts, as well as those of the Germplasm Bank Coordinator Cristian Zavala Espinosa, there have been significant improvements in the genebank since the 2019 Review. The merging of genebank operations and staff, both in physical spaces and in the workflows and operations manuals, was highly successful, with all staff retained and transitioned to teams that focus on genebank operations.

CIMMYT curators and staff, with support from management, addressed nearly all the 2019 Review recommendations. This willingness to receive input and suggestions continued to be apparent in the 2025 Review process. Items from the 2019 Review that were originally viewed as not feasible were fully incorporated into genebank operations, with the merging of separate activities for wheat and maize into a single CIMMYT genebank managing two crops. This merger allowed for efficiencies in genebank processes, staff allocation, and the application of resources to address significant issues.

There have been many improvements since the 2019 Review, and here we highlight a few highly significant accomplishments. Of the 19 recommendations in the 2019 Review, 15 were fully addressed, and four have been partially addressed. The wheat collection has undergone a complete overhaul. Over 24,000 accessions, comprised primarily of older breeding lines, were removed from the collection. The remaining materials were removed from their previous packages, cleaned, analyzed, and repackaged in a "kangaroo" system before placement in the active and base collections. The new packaging and barcoded labels have improved seed processing activities as well as the security of the collection at the CIMMYT location. In addition, safety duplication deposits were made to the National Laboratory for Genetic Resources Preservation in Fort Collins, Colorado and to the Global Seed Vault in Svalbard. The identification and use of an alternative wheat regeneration site have allowed the wheat collection regeneration backlog to be eliminated. An efficient bulking system is being implemented to perform the necessary phytosanitary testing and certification.

The maize collection repackaging effort is underway, with about two-thirds of the collection removed from the plastic containers and placed into aluminum bags. There were two issues with the bags, on the one hand, apparently, they were too expensive to purchase from the UK, which creates budget constraints, and on the other hand, they are not thick enough to be able to pack maize seeds under vacuum, since they are poked by some seed types (such as popcorn). Alternative bag providers have been suggested, so hopefully the repackaging effort for maize can be completed soon. Maize regeneration remains a challenge, and the ongoing efforts to identify alternative regeneration locations for maize are acknowledged. Seed health issues in maize are ongoing, and some suggestions to address them are provided in this report.

CIMMYT staff are now using GRIN-Global Community Edition (GGCE) in their workflows, and GGCE staff training is ongoing. This adoption of GGCE and barcodes for labelling, laboratory, and field activities has increased productivity and eliminated the need to write labels and collect data by hand, a frequent source of errors. Data curation has been improved for both collections, with an average Passport Data Completeness Index (PDCI) of 7.47 and the inclusion of viability and seed health data in GGCE. The 2025 medium- and long-term storage validation tests were successful, demonstrating sufficient data availability in GGCE and that the accessions can be located at their indicated positions in the vault.

The sensor implementation for online datalogging of temperature and relative humidity in cold storage and drying rooms, both at CIMMYT and at field sites, is a vast improvement over the manual checks performed previously. Vault security has significantly improved, with an alarm response time (by genebank staff) of less than one minute. In addition, cameras provide images and audio via Wi-Fi in the event of personnel emergencies in the vault. Although the vault is secure, CIMMYT policies currently prohibit locked doors for safety access reasons. Specific rooms and spaces with equipment and germplasm should be secured in a manner compliant with CIMMYT policies.

The CIMMYT genebank is currently on track to reach performance goals, with continued efforts as defined in this report. It is recommended that CIMMYT address recommendations without waiting for the new building to be funded and built.

Table 1. List of recommendations

ID	Critical/ Major/ Minor observation	New Recommendations	Proposed activities to address recommendations
1	Critical	Improve seed processing and drying room facilities so they are fit for purpose (equipment, size and conditions).	Identify workflow/facilities to improve seed processing and drying capacity, which could be the renovation of existing space to improve temperature/RH conditions.
2	Critical	Reduce LTS to -18C	Turn the knob.
3	Critical	Use automated methods for seed weight acquisition and seed sorting	Identify, purchase and use equipment so that seed processing can be more fully automated, such as for weight data management and seed sorting.
4	Critical	Secure access to the genebank building and facilities	Lock the genebank building or rooms containing germplasm/equipment when the facility is unoccupied.
5	Critical	Improve phytosanitary management of maize field regeneration	Consider netting or screenhouse production for critical accessions. Determine if diseases originate from the field or from within seeds. Adapt agronomic practices to minimize pests and diseases (sticky cards, nutrition). Ensure field managers understand the critical nature of field pest management. Take immediate action when pests are first identified in the crop. Continue crop rotation practices for both crops.
6	Critical	Improve the availability of both crops	Resolve seed health testing backlogs for both crops.
7	Major	Implement best practices for seed processing	Merge maize and wheat seed processing activities into one room with controlled humidity and temperature conditions to minimize fluctuations in seed moisture content.

ID	Critical/ Major/ Minor observation	New Recommendations	Proposed activities to address recommendations
			Consider placing seeds for both crops at optimum moisture content in the drying room within the seed processing room. Use mesh bags to decrease seed drying time. Do not open cold seed bags until they have reached room temperature. Package remaining maize seed into 3- or 4-ply laminate bags. Determine 100 seed weight for wheat accessions (as convenient during other activities). Avoid manual sorting. There are machines already used in the seeds industry that are able to sort the seeds by weight or for example viability with X-ray techniques (i.e., seed sorting machines). Determine seed moisture curves for improved facilities/conditions/crop to limit excessive testing of seed moisture levels.
8	Major	Improve maize regeneration to obtain higher quality seeds	Continue to build relationships to outsource maize regeneration activities. Optimize planting date to account for the physiology of the accession and to avoid extreme temperature conditions during pollination. Adapt agronomic practices to minimize pests and diseases (sticky cards, nutrition, etc.). Reallocate staff from wheat to maize to address the maize regeneration and processing backlogs. Consider regenerating fewer accessions per location to improve the management and quality of regeneration. Make balanced maize sample packets larger (>1 seed per cob, 75 cobs) so only one balanced sample is used for each regeneration.
9	Major	Optimize safety duplication procedures	Going forward, increase the number of seeds per accession in the safety duplication packages (3x regenerations each). For maize, use balanced samples for safety duplication, when possible. Safety duplicate *Tripsacum* at two locations, with 3 plants each. ILRI has agreed to receive a copy of the *Tripsacum* collection to be conserved in Ethiopia (plants in the field).
10	Minor	Reinforce succession planning, shadowing of staff and transfer of knowledge between staff especially those retiring. Develop a scientific staffing plan to address future needs (i.e., the use of genotyping to rationalize collections).	Regularly update staff succession plan. Hiring plans to address scientific capacity needs should be implemented.

ID	Critical/ Major/ Minor observation	New Recommendations	Proposed activities to address recommendations
11	Minor	Continue to support staff training opportunities	Ensure the capacity of staff to manage the collection is up to date and that all genebank staff are proficient in GGCE. Pursue staff online training opportunities when available.
12	Minor	Take the lead on updating the wheat and maize Global Crop Conservation Strategies.	Use CIMMYT's strong relationship with other genebanks including the CGIAR Latin America CoP to update the wheat and maize Global Crop Conservation Strategy and to further demonstrate CIMMYT's global leadership and to foster additional new relationships.
13	Minor	Continue to improve data management processes.	Avoid manual data recording and validation during viability testing. Continue to collect and upload images to GGCE & Genesys. Pursue automated characterization data collection from images, particularly for maize, including the use of the Videometer. Prioritize the use of genetic data to inform collection management for both wheat and maize, including the identification of duplicates & for QA/QC during regeneration and processing. Finalize the genebank dashboard.
14	Minor	Dispose of seeds that have been de-accessioned.	Dump the bags.
15	Minor	Update SOPs to reflect actual operations.	See reviewers' suggestions in Annex 4.
16	Minor	Continue to follow-up with breeders to obtain information about use.	Use CIMMYT institutional systems to demonstrate genebank impacts and intensify outreach to germplasm recipients (current and previous).
17	Minor	Promote and share genebank success stories.	Coordinate with outreach teams at CIMMYT, Crop Trust, and others to widely share the genebank's successes.

Table 2. Updates since the last genebank review

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

	2019 Recommendations	2025 Status	Comments
1.	Reinforce succession planning, shadowing of staff and transfer of knowledge between staff especially those retiring	2=Partially addressed	Continued efforts for staff educational opportunities are encouraged. Hiring plans to address scientific capacity needs should be written.
2.	Integrate and unify conservation activities for wheat and maize into a single genebank by sharing staff, methodologies, equipment, expertise, etc., including establishing biweekly meetings of all staff	3=Fully addressed	Significant operational improvements were noted as a result of the successful unification.
3.	Implement barcoding and use of mobile devices in all genebank operations, including introductions, regeneration, viability testing, and seed health testing. Barcodes and mobile	2=Partially addressed	Significant advances have been made, and staff continue to identify and implement additional opportunities.

2019 Recommendations	2025 Status	Comments
devices should be integrated into the data management system		
4. GGCE data should be systematically reviewed and actively curated by performing integrity checks, adding missing data, curating virtual accessions, correcting safety duplication data, and improving passport data completeness.	3= Fully addressed	A significant accomplishment.
5. All terms (e.g. "Availability") in the GGCE database should be properly defined (data dictionary), consistently used and understood by all staff. Where necessary, fields should be created to record compliance with critical steps managed by other units (e.g., health tests, SMTA). Reporting scripts should be written to ensure that data queries are able to (1) consistently return reliable up-to-date information and (2) prioritize accessions for viability testing, regeneration and safety duplication	3= Fully addressed	Significant advances already achieved, and the new dashboard is an exciting effort.
6. CIMMYT staff working in the genebank associated units should be aware of FAO genebank standards and international policy and standards related to the exchange of germplasm. A formal document should be available to indicate CIMMYT's compliance with such standards	3=Fully addressed	Information is provided in the SOP, with some minor edits requested.
7. Review and report on options to regenerate teosinte, wheat CWR and winter wheat in alternative locations or outsource the work	3=Fully addressed	This ongoing effort must be continued, and significant improvements are noted.
8. Internal redundancy in wheat collection should be addressed and a revised policy on seed lot management developed to ensure number of lots (inventories) is significantly reduced and kept to a manageable number.	3=Fully addressed	The curator is commended for the tremendous effort, and it's recognized that these efforts will continue as the newly available genotypic data are analyzed.
9. Revise procedures for wheat regeneration to take account of (1) reconsidered threshold for regeneration of CWR, (2) characterization practices, (3) alternative options for regeneration of winter wheat, CWR, and (4) need to reduce time between harvest and storage.	3=Fully addressed	Minor edits are suggested for the SOPs.
10. Review maize regeneration policy, thresholds, management of seed lots and consider what can be done that has not been tried before to substantially improve regeneration success rate. Failing an improvement CIMMYT should consider alternative hosts for the parts of the collection that cannot be regenerated	2=Partially addressed	The ongoing efforts are recognized and should continue to be actively pursued.
11. Response plans to (1) the alarm system and (2) in the case of an emergency should be revisited and improved in full communication with maintenance staff and all other relevant responsible people.	3=Fully addressed	Significant improvements over 2019.
12. Complete an inventory of the wheat accessions that are currently stored in paper or unsealed bags, test their viability and, if necessary, regenerate or replace the accessions in LTS.	3=Fully addressed	This large-scale significant effort is appreciated.

2019 Recommendations	2025 Status	Comments
13. A unified SOP for wheat and maize viability testing needs to be developed and current processes revised to ensure that;(1) initial viability of an appropriately representative sample is tested for both crops, (2) seed dormancy is addressed and taken into account in determining viability and (3) monitoring intervals are revised based on scientific evidence	3= Fully addressed	Minor edits are suggested for the SOP.
14. Data entries for viability need to be corrected and data entry processes revised for: (1) date of last viability test (where the date of data upload has been erroneously recorded) and (2) flagged clearly where extrapolated data are recorded and distinguished from actual results	3= Fully addressed	Viability data recording is significantly improved. Data in the TZ testing data fields must be reviewed.
15. Ensure SMTAs accompany all accessions introduced into the collection and are electronically available both for acquisition and distribution. Use of easySMTA is recommended	3= Fully addressed	Implementation of the easySMTA is a significant achievement.
16. Confirm with ITPGRFA experts that the AMTA is a legal substitute for the SMTA and that it will withstand scrutiny in a legal situation by end of 2019	3= Fully addressed	Genebank has adopted the easySMTA.
17. The acquisition and curation policy for both maize and wheat collections, including the automatic introduction of breeding lines, should be strengthened so that decisions to introduce materials are based upon an agreed scope and strategy and implemented by managers who are given the appropriate authority to implement the policy	3= Fully addressed	Minor edits are suggested for the SOP.
18. The composition of maize and wheat collections requires critical assessment to reduce over-representation of improved materials (especially for long-term storage and safety duplication)	3=Fully addressed	These significant efforts are recognized.
19. Collections of species other than wheat and maize in storage in CIMMYT's cold rooms should be transferred to genebanks better positioned to actively manage them. Barriers preventing this process from happening should be identified and addressed by the end of 2021	2=Partially addressed	It is noted that the CIMMYT genebank is still looking for a genebank to accept the materials, and the materials are not being curated in the meantime. The Treaty should be approached to find a suitable location for these collections.

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

2 Assessment of genebank activities to sustain essential operations

2.1 Availability of germplasm

- Monitoring of genetic integrity
  (taxonomic identity, labels, tracking of germplasm in workflow)

The management of germplasm in a genebank requires rigorous attention to taxonomic identity, accurate labelling, and robust tracking systems to ensure integrity throughout the workflow. Following the 2019 Review recommendations, activities have been streamlined and merged into five core processes supported by IT infrastructure and Quality Management Systems (QMS).

A major undertaking involved the rationalization of wheat collections, reducing the number of accessions from approximately 150,000 to 124,000, representing material from 150 countries. This included addressing redundant breeding material and segregating populations, which were identified and removed to improve efficiency. Despite these efforts, there are numerous boxes of materials that are destined to be removed that are taking space in the Long-Term Storage (LTS), and another round of curation based on genetic data is planned. It is recommended to dispose of all excess material as soon as feasible.

One of the most significant operational challenges was relabelling and repackaging. Over one million seed packages were opened and the most recently regenerated inventories with sufficient availability were selected to eliminate inventory redundancies, which were then re-packaged with updated seed weights and QR codes for digital traceability. All data were meticulously updated in GGCE to maintain accuracy. This system now serves as the backbone for tracking taxonomic identity and distribution history.

To optimize distribution, “kangaroo packages” (a larger-quantity package with ready-to-ship smaller foil packets to avoid opening and closing the original bag to remove seeds for distributions) were prepared for the most requested wheat materials over the past five years and for accessions identified for Multi-Trait Selection. Smaller packets for future seed viability testing were also packed in the kangaroo system. While these packages are costly, their use has dramatically improved turnaround times, reducing the seed dispatch process from 50 days to just 2 days.

The repackaging and relabelling effort is still ongoing for maize. One third of the collection is still in bulk plastic containers (with unmaintained moisture content) and in need of updated QR labels to track the accessions through the workflow and to avoid manual labelling mistakes. The Review Team recommends contacting Latin American regional sources for tri-laminated or tetra-laminated aluminium foil bags as those found in Agrosavia (Colombia) for coffee producers. Agrosavia did tests with eight different providers and chose the one which was best for germplasm seed conservation.

The integrated approach that is being implemented, combining taxonomic precision, advanced labelling, IT-enabled tracking, and QMS oversight, will strengthen the genebank’s capacity to support global breeding programs efficiently and reliably.

- Monitoring of viability
  (viability testing)

Seed viability testing is a cornerstone of genebank operations, ensuring that accessions remain viable in both medium-term storage (MTS) and long-term storage (LTS). Over the past two years, the program has scaled up dramatically, increasing from 2,000 tests in wheat annually in 2021 to approximately 90,000 samples per year. This expansion has enabled testing of nearly all accessions in the MTS and LTS, achieving 95% coverage for the wheat collection.

This collective team effort is remarkable and represents a paradigm shift from the previous situation.

Testing protocols vary by crop: wheat seeds are germinated in Petri dishes, while maize seeds are placed directly on paper towels in a “taco” format; both are adequate and fit for purpose. Two replicates of 25 seeds are used in both cases. The effort is sustained by a dedicated team of two permanent staff and three temporary technicians, who have transitioned from a routine capacity of 5,000 tests for both crops to managing large-scale operations efficiently. Despite the surge in workload, the team maintains clear capacity planning and scheduling.

All viability data are accurately recorded in GGCE, avoiding extrapolation and ensuring traceability. Workflow improvements now integrate viability and seed health testing before accessions are made available for distribution, and gaps that emerged during the pandemic have been closed.

To manage this scale, inventories should be scheduled using calendar-based tasks for each accession. Currently the Kew Garden calculator and Fiona Hay’s formula (Fiona R. Hay, Katherine J. Whitehouse; Rethinking the approach to viability monitoring in seed genebanks. Conserv Physiol 2017; 5 (1): cox009. doi: 10.1093/conphys/cox009) guide decisions on when to retest viability, and future plans should include researching and adopting non-destructive viability testing methods, such as the use of Videometer estimations or X-ray analysis, if these methods are demonstrated to be acceptable replacements for germination assays.

Current long-term viability strategies follow Dr. Taba’s standards for maize and wheat collections, with checks at 15–20 years and subsequent intervals every five years. Historical data show that even older wheat accessions (up to 72 years) retain viability levels of around 83%. Monitoring requirements have been reduced for wheat following the immense repackaging and viability testing efforts, while maize continues to be monitored in both active and base collections. Lots are tested simultaneously in LTS and MTS; if discrepancies arise, MTS testing may be prioritized for efficiency. Additional research may reveal that it is acceptable to have extended viability testing intervals (beyond 5 years) after the initial 15-20 year tests. A recommendation to improve viability and align with genebank standards includes adjusting storage temperatures from -15°C to -18 or -20°C in LTS. Grain type and moisture content influence longevity; for example, soft grains with 9% humidity deteriorate faster. Optimization efforts aim to maintain high viability without extensive manual processes, relying instead on validated workflows and digital systems.

- Monitoring of germplasm health
  (germplasm health testing)

Seed health testing is a critical component of germplasm management, ensuring that distributed material meets phytosanitary standards and minimizes the risk of pathogen spread. Currently, seed health services are provided by the Germplasm Health Unit (GHU), which operates independently from the genebank and is very well managed by Noemi Valencia. The GHU methodologies are according to the state of the art and fit for purpose. The GHU is aware of the critical diseases for both wheat and maize, including quarantine diseases, for both the import of new accessions as well as for the distribution of accessions outside of Mexico. GHU issues the correct Phytosanitary Certificate according to the destination country. If documentation is missing, health tests are conducted before shipment, and results are recorded in GGCE for compliance and transparency.

The backlog on health testing and the presence of diseases following recent maize regenerations are the main weaknesses of the CIMMYT genebank. Currently, only about 37% of accessions have a certified health status. This backlog largely resulted from changes to testing protocols introduced in 2018 to address new pathogens.

A key risk that requires careful management is the continued emergence of new pathogens and diseases, which could necessitate further revisions to testing protocols. Such changes raise concerns that similar backlogs could recur in the future and pose significant operational and financial challenges, as health testing is highly resource intensive.

To optimize costs, GHU employs bulk testing strategies: if a bulk sample tests positive, all individual accessions within that bulk are subsequently tested. This approach has enabled significant progress. By 2025, testing expanded to 23,000 accessions, supported by emergency funds because routine budgets could not cover the full cost. The bulk approach is well justified in terms of costs and optimization of the operations. Additionally, when new pathogens emerge, there is no need to retest the full collection, but only when the accession is "opened" again for distribution or new viability testing. Historically, seed health testing was performed only upon request for distribution due to budget constraints. Moving forward, the challenge is to establish sustainable funding and workflows so that seed health testing is performed on the collection proactively. In wheat, less than 2% of accessions are rejected for health reasons, indicating relatively low pathogen incidence. For example, in a recent bulk test of 1,000 samples (25 accessions per bulk), only 38 out of 1,000 were positive. Maize presents a different scenario because bulk testing of 10 maize accessions revealed 40% infection rates for certain pathogens from some regrowth locations. This high infection rate makes bulk testing much less effective in maize than for wheat.

Seed health monitoring is functional but requires reinforcement through improved field management and preventive measures. The ultimate goal is to certify that all accessions are clean and healthy before distribution. Achieving this will demand a combination of technical innovation, good financial planning, and strict adherence to phytosanitary standards, which are the same for both clonal and seed crops.

- Ensuring sufficient stocks of germplasm
  (regeneration, multiplication)

Seed regeneration and multiplication are essential for maintaining the viability and availability of germplasm collections, particularly for crops like maize and wheat that have high global demand. The maize collection faces unique challenges due to its size, diversity, and the logistical complexity of regeneration. Plans are underway to create compartments in a GH to regenerate more than 200 Teosinte accessions in a few years, while it has been difficult to identify alternative regeneration sites, despite the genebank's offer to cover costs. This has limited the possibility of clean regeneration in alternative sites.

Distribution pressures remain high, with 795 Teosinte samples shipped in the last ten years to 24 countries. Concerns about regeneration for distribution have led to new agreements for maize regeneration: SENASICA now permits regeneration outside CIMMYT's station in Jalisco, and Corteva will provide in-kind regeneration in northern Mexico, which is very good since it is a win-win relationship. Toluca remains a key site. Unfortunately, negotiations with INIA in Peru stalled due to their high staff turnover. A new MOU with a Peruvian university is promising, and regeneration options for 2026 include sites at higher altitudes.

Agronomic improvements, such as staking plants to prevent ears from touching soil and opening ears before harvest for better drying, are being implemented, along with integrated pest management (IPM). These efforts are a good step forward, but are insufficient considering the health challenges for maize regeneration. Improved agronomic practices, such as different planting dates to optimize bloom time according to accession characteristics and the environmental conditions of the research station, are routinely implemented.

Biostimulants such as EliZea and Neptunion may improve root development and could induce early flowering to avoid pollen losses under heat conditions. Additionally, for challenging varieties, sowing more seeds and pollinating more female maize flowers per accession should also be considered to avoid repeated regeneration cycles (if there are fewer than 80 ears of maize, the accession is considered not regenerated). The genebank should follow up on the discussed experiments to determine if the maize disease issues are seed-borne or are being introduced from the field conditions. Additional pest tracking in the field, such as blue sticky traps for thrips and yellow sticky traps for whiteflies, should be used to monitor pests that transmit disease. Field managers should be actively engaged in pest and disease management discussions to understand the critical nature of disease and pest threats to genebank collections, and why genebank regeneration activity management may vary from standard production conditions. Immediate action should take place when pests first appear in the crop. The current crop rotations should be continued to lessen the disease presence in the field and to improve soil health and growing conditions. A smaller number of accessions could perhaps be regenerated with more dedicated management to make sure regenerations do not need to be repeated until agronomic practices are perfected. Customization of nutrition and treatments for high-altitude maize should remain a research priority.

Quality Management Systems (QMS) have been revalidated, ensuring SOPs and ISO 9001:2015 QMS compliance for regeneration workflows. Demand for landraces is strong, with requests from 81 countries for seven major Mexican race groups, though new collections are restricted by national regulations. Breeders increasingly request CIMMYT inbred lines for traits like resistance to Tar Spot Complex (TSC) and Turcicum Leaf Blight (TLB), underscoring the need for closer collaboration between genebanks and breeding programs. Disease remains a concern, with 19% infection observed in maize and 2% infection observed in wheat in the first ten months of 2025.

Operationally, maize regeneration targets around 1,000 accessions per year, prioritizing landraces. If regeneration fails after three seasons, accessions are archived unless new external options (e.g., Peru or Corteva) are available. Recently, there have been an average of 10,000 wheat regenerations, with recent efforts focused on clearing backlogs of crop wild relatives and low-viability samples. Despite occasional setbacks, such as high salinity fields, recent seasons have shown strong performance in Mexicali.

Future priorities include scaling regeneration capacity, integrating digital monitoring, and formalizing rematriation processes for community genebanks. These efforts will ensure that both maize and wheat collections remain viable, accessible, and responsive to global breeding and conservation needs. Given the success in clearing the wheat backlog, it is highly recommended that staff allocated to wheat be re-allocated to maize so they can also catch up on the backlog and support maize regeneration. Maize regeneration efforts should not be scaled up until the health standards are raised for this crop. Maize regeneration failures due to poor seed health highlight the need for preventive strategies, such as consideration of screening and controlled environments for the regeneration step. To mitigate risks, the genebank should also explore screenhouse and net-house solutions, similar to ICRISAT’s large-scale net systems, to reduce field insect, the virus disease carriers, and contamination.

Additional measures include field rotation, buffer zones, and double production cycles to ensure sufficient healthy seed. These practices must be reflected in the genebank's operational plans and budgets.

2.2 Security of the crop collection and the genebank

- Safety and security of the crop collection
  (first- and second-level safety duplication)

Safety duplication is a fundamental pillar of genebank conservation, ensuring that genetic resources remain secure against loss from natural disasters, political instability, or operational failures. For maize, the Mexican collection is safeguarded through first-level duplication at INIFAP in Jalisco, while second-level duplication is achieved via long-term storage (LTS) in global repositories. Currently for both collections, 87% of the collection is duplicated at Fort Collins (with boxes ready to be shipped to reach above 90%), and 90% at the Svalbard Global Seed Vault, reflecting strong progress toward achieving performance targets.

Safety duplication is embedded in the genebank's conservation process and governed by Standard Operating Procedures (SOPs) available in both Spanish and English. These protocols ensure consistency across crops and storage sites.

For vegetatively propagated species such as *Tripsacum*, duplication should involve maintaining at least three plants per accession under active and backup conditions with proper management. Currently, the vegetatively propagated collection is in the field, as well as a duplicate, with two plants in pots per accession, in a screenhouse in Texcoco. However, the screenhouse collection has a very high mortality rate, and dead plants need to be replaced from the field collection. A new safety duplication site at ILRI in Ethiopia will improve the security of the vegetatively propagated *Tripsacum* collection.

Collaborations with international partners strengthen redundancy and CIMMYT is also contributing to keeping safety duplicates from other collections in LTS. ICARDA, for example, maintains complementary collections with minimal overlap. Historical "black boxes" from Syria, characterized in the 1990s, were recently reopened and returned from CIMMYT to Lebanon, reinforcing trust and transparency. In October 2023, CIMMYT received 664 maize accessions from IITA for long-term black-box conservation. Plans are underway to receive 300 black boxes from ICARDA and CIAT, further expanding safety coverage within CGIAR. Communication with ICARDA remains strong, and CIMMYT continues to confirm shipments of safety-duplicated seeds.

Looking ahead, the genebank should certainly increase the number and quality of safety duplicates. For maize, this means producing balanced samples rather than relying on leftovers from regeneration. Balanced samples require increasing the number of kernels selected per ear (not an increase in the number of ears sampled) to avoid splitting into multiple packages, which complicates logistics and raises regeneration costs. This approach ensures genetic integrity and simplifies duplication workflows. Additionally, enough seeds for 3 regeneration cycles should be packed for each safety duplicated accession going forward.

Safety duplication is not static; it evolves with operational realities and crop-specific needs. By reinforcing partnerships, improving sample balance, and adhering to validated SOPs, the genebank secures its collections against future risks while maintaining global accessibility.

- Safety and security of the genebank facilities

(infrastructure, field, equipment, supplies)

Efficient seed conservation and processing depend on well-trained staff, well-designed infrastructure, appropriate equipment, and reliable supplies.

The conservation vaults are excellent and both the LTS and MTS collections are secure. However, the standard conservation policy establishes a temperature requirement of -18°C to -20ºC and currently the LTS vault temperature is established at -15ºC. It is recommended to lower the temperature to at least -18ºC. To maintain the quality standard, the facility operates with duplicated cooling systems, including two pieces of equipment dedicated to temperature control, ensuring redundancy and reliability, which exceeds the minimum standard. Additionally, the vault is equipped with solar panels, contributing to energy efficiency. The generated solar energy is discounted from the electricity bill, and any surplus can be sold to the Texcoco municipality, creating an added sustainability and economic benefit. This is very good.

Current facilities for seed processing face critical constraints, particularly in maize drying and processing. Environmental conditions in the drying rooms vary: Taba's room operates at 10°C and 18% Relative Humidity (RH), Cencal at 16°C and 16% RH, and the wheat drying rooms at 11°C and 16% RH. In Agua Fría (where breeding materials from the Global Maize Program are conserved), the cold rooms show higher humidity (46–60%) at 12°C, while another cold room records 89% RH at -13°C, creating challenges for moisture control.

For maize, moisture content is monitored from field harvest through processing. After harvest, cobs enter the drying room for at least one week, during which RH drops. When kernels reach 15% moisture or less, shelling begins, followed by humidity tests. Seed processing for MTS and LTS occurs only when moisture reaches 6–8%, typically requiring two checks, with a third for flinty accessions. Wheat often meets moisture targets (around 7%) after the first test because Mexicali offers ideal conditions for wheat drying due to its dry climate and absence of *Tilletia*, while maize faces challenges during rapid seasonal transitions, requiring precise planting schedules.

The maize cob drying room requires additional space to accommodate increasing volumes. One immediate solution is relocating maize kernel bags ready for processing to the drying room adjacent to the processing area (which will presumably have more space when there are fewer numbers of annual wheat regenerations). Using mesh bags for maize drying can also significantly reduce drying time and improve airflow. Current bottlenecks in the drying rooms could be addressed by using short-term (experimentally determined) heat treatments (36°C) to achieve 6–8% moisture content, matching seed production standards without compromising longevity. However, updating the drying rooms is a better solution.

Processing room utilization should be altered such that both crops are processed in a single climate-controlled room to minimize fluctuations in seed moisture content. Aggressive humidity control is essential, as prolonged drying periods—currently up to 180 days—must be shortened to maintain seed quality and operational efficiency. Reorganizing the processing room by removing non-essential equipment and converting one or both warehouse rooms into additional drying spaces will help meet these goals.

Best practices must be enforced, such as never opening cold seed bags until they reach room temperature, to prevent condensation and moisture damage. For packaging, tri- or four-ply laminated bags should be adopted for maize vacuum sealing to enhance long-term storage integrity. Vacuum packaging is recommended for both crops, providing puncture proof bags are identified for use in maize. This is because 1) humidity strongly affects seed longevity, and 2) it is easy to visually determine if the seal of the bag has been broken.

An inventory of equipment is maintained, and all acquisitions follow CIMMYT's internal procurement process, which requires justification for each choice. Planning is highly organized, with needs anticipated six months in advance to avoid last-minute urgencies, especially before planting dates. For specialized equipment, sourcing can be challenging. For example, UK suppliers provide bags for Svalbard, and these are expensive for CIMMYT to acquire, especially considering the broker, tax, and transport costs. Lead times remain a concern: a seed sorter took months to acquire, a thermohygrometer required nine months, and a cleaner has been pending for over a year. Delays often depend on cost thresholds (e.g., items over $2,500 or $50,000). Efforts are underway to improve efficiency, but bottlenecks persist, particularly in the legal department, which complicates processes like in-kind contributions.

Future plans should include merging maize and wheat processing activities into a single controlled environment, placing seeds at optimum moisture levels in drying rooms within the processing area, and implementing automated systems for sorting and weight determination. Long-term storage conditions should be standardized at -18°C to align with international best practices. Improvements have also been made to the facilities, and the adoption of remote sensors is especially commendable. By upgrading infrastructure, optimizing workflows, coordinating activities between crops, and adopting advanced technologies, the genebank can significantly reduce processing times, improve seed quality, and meet global conservation standards without waiting for new building projects.

2.3 Documentation and data availability

- Information management system for monitoring and management
  (IT system and equipment; barcoding)

CIMMYT's robust IT infrastructure underpins the genebank's ability to manage, curate, and share data efficiently. Despite these advances, image integration remains incomplete. Although GGCE does not yet host all of the data, maize characterization includes 12,263 accessions with images and wheat has 4,292 images. Current efforts focus on capturing spikes and kernels during regeneration and extracting samples from active collections for imaging. The genebank is investing in Videometer technology, the most advanced and expensive scanner available, to support multispectral analysis and algorithm development for automated characterization. Although samples were previously sent to the U.S. for analysis without feedback, internal expertise is now being developed, and AI-based characterization is under evaluation.

Barcoding and labelling processes are being modernized to improve traceability; however, full integration in genebank processes is ongoing. For example, optimization of viability processing is possible without manual writing and validation and should truly rely on automatic QR reading. All staff should be trained in GGCE operations, thus improving workflows. Future plans include linking phenotypic and genotypic data for comprehensive accession comparisons, leveraging AI tools developed in Peru to accelerate request processing and integrate with GGCE.

By combining advanced imaging, automated characterization, robust backup systems, and integrated data platforms, the genebank is moving toward a fully digital, interconnected conservation ecosystem that supports efficiency, transparency, and global collaboration.

- Security and availability of germplasm data
  (data backups; updates to Genesys; passport, characterization, and evaluation data)

Data security and backup protocols are well established. All data are backed up nightly to Amazon cloud storage, validated by Juan Carlos Moreno Sanchez, while GGCE also maintains backups. Environmental data, such as temperature and humidity, are archived for long-term reference. Personal computers synchronize through OneDrive, and servers operate on virtual machines. Significant progress has been made in passport data curation, with over 30,000 accessions updated to include geolocation details, as available. This required two years of effort from two temporary staff members, far beyond the initial six-month estimate, due to the complexity of historical records, such as changes in place names in countries like China and Turkey. As a result, the Passport Data Completeness Index (PDCI) has improved from 6.47 to 7.47, exceeding the 6.0 target, which is a very good achievement. Furthermore, characterization data is automatically uploaded to GGCE, streamlining data management and ensuring compliance with global standards. Wheat data should include 100 seed weight for each accession (to be collected when bags are opened going forward). Maize seed data collection could be automated through image analysis techniques.

Integration of data systems is a priority. The fieldbook is not yet connected to GGCE, but plans are underway to consolidate all data streams within GGCE, which is considered stable and is widely used across CGIAR. Transitioning from legacy tools like Curator Tool to GGCE has been challenging, requiring mindset changes among users. Training videos and feature adaptations aim to ease this transition, supported by Juan Carlos and Alex, who manage reporting for Crop Trust and Accelerator projects. A dashboard for management is in development to simplify data visualization, which can certainly increase the usefulness of these tools. Image data management requires additional coordination because of GGCE limitations. Genesys is able to host images, and efforts to upload images should be synchronized.

The most original sample is always conserved as the Reference. Characterization and evaluation data are collected, as applicable, during regeneration activities. Genetic data integration remains pending. There is a wider need for genomic data to be accessible through interoperability between GGCE and genomics databases to aid in genebank management applications. Currently, genetic data are stored in Germinate; this data will eventually migrate to CGIAR platforms, aligning with global genebank practices. Open-access policies are in place, and allele mining projects are expected to strengthen collaboration with breeders. For maize, subsets are available in Genesys, though requests have not yet materialized. Environmental GWAS analyses are ongoing, supported by biometric expertise and international collaborations.

3 Key performance indicators

Table 3. Status on key performance indicators and targets for long-term support

Mission of the Crop Trust	Key performance indicators	KPI status*	Targets for long-term funding support	Target status
Promote the availability of PGRFA	Number of accessions that are legally available for distribution Number of accessions that are available in the Multilateral System (MLS)	151,275 (both) 28,441 (m) 122,834 (w) 146,550 (both) 25,885 (m)	Target 1: Availability 90% of collection clean of pathogens of quarantine risk, viable, and in sufficient quantity to be immediately available for national and international distribution from medium-term storage.	Not yet achieved** 37% (both) 30% (m) 39% (w)

Mission of the Crop Trust	Key performance indicators	KPI status*	Targets for long-term funding support	Target status
	Number of accessions that are physically available for distribution	120,665 (w) 56,682 (both) 8,554 (m) 48,128 (w)		
Endeavor to safeguard collections of unique and valuable PGRFA held *ex situ*	Number of accessions conserved as seeds in cold storage, as live plants in the field, and other plant materials in *in vitro* and cryopreservation. Number of accessions conserved in long-term storage (LTS) in two locations, including the Svalbard Global Seed Vault (seed crops) Number of accessions conserved *in vitro* in slow growth conditions or in cryopreservation at two locations (clonal crops)	153,040 (both) 28,779 (m) 124,261 (w) 132,328 (both) 22,646 (m) 109,682 (w) n/a	**Target 2: Safety duplication** For seed crops: 90% of collection in LTS at two locations and also in Svalbard Global Seed Vault For clonal crops: 90% of collection duplicated *in vitro* or in cryopreservation	On track*** 86% (both) 79% (m) 88% (w)
Promote an efficient goal-oriented, economically efficient and sustainable global system of *ex situ* conservation in accordance with the International Treaty and the GPA	Elements of QMS in place (science and operations, policy, risks, staff, equipment, infrastructure and reagents, user satisfaction, information management, supplies and services)	8	Target 3: QMS Eight elements of genebank QMS in place	Achieved 100%
Promote the regeneration, characterization, documentation and evaluation of PGRFA and the exchange of related information	Number of accessions with passport data uploaded to Genesys Passport data completeness index (PDCI) Number of accessions with characterization and/or evaluation data uploaded to Genesys	153,040 (both) 28,779 (m) 124,261 (w) 7.47 (both) 44,398 (both) 28,759 (m) 15,639 (w)	**Target 4: Data availability and completeness** 90% of accessions uploaded to Genesys Average PDCI > 6	Achieved 100% (both) 100% (m) 100% (w)
Promote national and regional capacity building, including the training of key personnel	Capacity building activities with NARS Number of participants, including key genebank staff, trained on performance areas related to above	24 (see business plan) 51 (see 2024 annual report)	Target 5: Capacity building Capacity building with at least five NARS (including other crop genebanks, regional/community organizations, and/or farmer groups)	Achieved 100%

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

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

**Health testing protocols were revised in 2018, resulting in a decline in availability figures. Prior to this change, 39% of wheat and 45% of maize accessions had been certified as free of pathogens of quarantine risk. Seed health testing for wheat has been intensified in 2025 to reach 90% availability in the coming year.

*** 90% is expected to be reached by early 2026. Materials are ready to be shipped to Fort Collins, USA.

4 Proactive management of the collection

- Genebank QMS

All elements of QMS are in place thanks to the ISO 9001:2015 Quality Management System certification that CIMMYT has for their operations. These audits guarantee that SOPs are in place and that calibration of all equipment is performed annually by a dedicated team, ensuring accuracy in humidity and temperature measurements. Also, such certification ensures that the distribution of seeds outside the country complies with national and international requirements.

- Risk management

Risk management in the genebank involves a comprehensive approach to security, procurement, legal compliance, and operational efficiency. Physical security is ensured through CCTV monitoring and on-site security personnel, while access to vaults requires card authorization. However, one of the challenges for security is a CIMMYT policy to keep buildings open at all times, which can jeopardize the genebank equipment and samples being processed, so it is highly recommended to lock at least all rooms housing key facilities inside the building.

User feedback mechanisms are evolving. User surveys assess distribution service quality and, after two years, track material performance through evaluations or publications. Response rates are low, prompting initiatives to engage users, such as embedding surveys in QR codes linked to passport or genetic data and piloting impact stories with IT. The goal is to make feedback appealing even years later. This is a common issue for many genebanks, so perhaps coordinated genebank follow-up activities could be pursued.

The genebank is considered the jewel of CIMMYT, central to its Genetic Resources Program (GRP) and critical for seed systems and community resilience. Excellence in science, innovation, and execution underpins CIMMYT's 2030 strategy, which achieved high execution in 2024. Future scenarios emphasize sustainability and prioritization: genebank activities are the bedrock upon which CIMMYT builds impact, requiring cost-effective, high-quality operations. Governance spans both physical and data sites, ensuring the genebank remains future proof. Celebrating achievements and promoting CIMMYT's impact, through DOIs, genotypic data sharing, and visibility, is essential for long-term success.

- Efficiency of genebank procedures

Genebank procedures have been streamlined as a result of the team's effort to optimize all procedures, including embracing the use of QR codes for planning and delivery, printing the labels upfront or directly on seed envelopes to avoid confusion, and embracing GGCE to record viability, health, weight, and characterization in real time. Procurement manages all supplies through CIMMYT's inventory system, ensuring availability for operations. For example, the genebank uses approximately 20,000 envelopes annually.

There is still room for improvement in maize regeneration agronomy practices. CIMMYT should utilize staff according to the prioritized needs in the maize collection (repacking maize from the plastic bottles to aluminium bags with QR code labels, improvement of drying procedures, or identification of accessions that need urgent regeneration or that are duplicated or have excess inventory). CIMMYT should assess its staffing needs and develop a staffing plan. Future hires should consider scientific needs and meet the necessary educational requirements for the technical level of the position.

The review panel considers that the following could contribute to increasing efficiencies and meeting standards in the CIMMYT operations:

- Install a coding system (barcode or QR code) on all accession containers.
- Update the inventory simultaneously with the installation of the labelling system.

- Train as many staff members as necessary to use GGCE on a daily basis, if necessary.
- For field regeneration, continue to use tablets that read barcodes for the collection of evaluation and characterization data.
- Automate the process of collecting data from maize accessions using image analyses.
- Improve the environmental conditions of the seed processing areas with controlled humidity and temperature.
- Record the 100 seed weight for wheat and not only the total weight.
- Reduce the temperatures in the cold vault from -15ºC to -18ºC or -20ºC.
- Consider a closed (insect-proof against whiteflies and thrips) glasshouse or screenhouse for the regeneration of delicate accessions (those unique accessions with few seeds left).
- Increase the safety duplication of the field *Tripsacum* collection to 3 copies per accession and automatic drip irrigation.

5 Effective enabling environment to support genebank operations

- Finances

Budget limitations remain a challenge. CIMMYT manages the largest collection among CGIAR genebanks but operates with a relatively low budget per accession. This discrepancy affects the ability to hire well-qualified staff and support research-level activities. Short-term solutions include hosting Master’s students and social service interns for up to 12 months, providing hands-on experience in field, lab, and processing tasks. However, even student placements require financial support and time-intensive training, making long-term arrangements more cost-effective.

Despite constraints, the genebank invests in innovation and research. Two recent theses focused on viability prediction using the Videometer alongside germination tests and on developing algorithms for descriptors such as taxonomy, seed shape, and seed size. These projects, conducted with Fiona Hay, achieved promising results, though trust in predictive models is still evolving. Such initiatives highlight the genebank’s commitment to bridging operational needs with scientific advancement, even when resources are limited.

- Policy

On the legal side, Standard Material Transfer Agreements (SMTAs) processing has improved significantly. New Easy-SMTA tool maintains necessary information and relays it to the Plant Treaty. GGCE also allows the recording of requests and automated reporting to Easy-SMTA. Users receive support to create Prior Informed Consent (PIC) numbers, but it remains a separate process. Challenges include training internal teams and clarifying PIC number sharing for universities with multiple scientists. All external requests are managed by curators Carolina Paola Sansaloni and Alberto Chassaigne Ricciulli, while internal CIMMYT distribution is exempt.

- Staff management and succession planning

Staff management in the genebank combines structured training, continuous skill development, and proactive succession planning to ensure operational excellence. Training begins with a clear distinction between temporary and permanent staff. Temporary staff undergo a two-week immersion program under the guidance of a mentor, covering all essential activities, ISO standards, and operational procedures. Once they demonstrate competence, they are integrated into routine tasks. Permanent staff receive ongoing training whenever new policies or technologies are introduced. Requests for specialized courses are coordinated through HR, with funds for external training when necessary, for example, seed quality management or advanced use of equipment like the Videometer. Training needs are identified individually, ranging from intermediate Excel for field data management to specialized workshops such as wheat harvest techniques. When internal expertise is insufficient, external specialists are engaged.

Annual reviews allow staff to request additional training, which managers approve based on operational priorities. For global tools like GGCE, not all team members can attend international in-person sessions, so a "train-the-trainer" approach ensures knowledge transfer internally. Continuous improvement is reinforced by ISO audits, both internal and external, and by participation in Communities of Practice within CGIAR. These networks support knowledge sharing on Genesys, GGCE, and germplasm management through annual meetings, workshops, and virtual sessions. Collaboration with CIAT and CIP strengthens seed quality management practices, while regional CoPs in Latin America and Africa foster experience exchange with NARS, overcoming challenges such as language barriers through translation.

Succession planning is a critical focus due to staffing gaps and retirements. While the team includes highly experienced personnel, many lack the academic qualifications required for advanced roles. The strategy is to replace retiring staff with candidates holding higher academic credentials, ideally moving from high school-level positions to Master's or PhD-level expertise. One example is to hire additional support staff with genotypic/genomics data analysis expertise to help implement the use of genotypic data for improved genebank management. ISO audits have highlighted the need to align Terms of Reference with these requirements. However, limited resources constrain recruitment, creating strain when overlapping training is needed for new hires. For example, Jesus Perales Escalante, head of regeneration, has been training Enrique Meraz Juarez for over two years to ensure continuity, despite Enrique's limited taxonomy experience.

There is also a clear interest in capacity strengthening through the Crop Trust's Genebank Academy, signalling a commitment to continuous learning and professional development.

Succession planning and staff development remain central to sustaining the genebank's role as a global leader in crop conservation. By combining structured training, collaborative networks, and targeted recruitment strategies, the genebank aims to secure a future workforce equipped with both practical experience and academic rigor, ensuring continuity and excellence in an increasingly complex environment.

- Leadership

The genebank has achieved a significant transformation, moving from a challenging situation to tangible progress, and is now on track to meet performance targets. This success is driven by capable staff and engaged, strong managers who demonstrate commitment through active participation and collaboration. Current leadership has been key, given that most of the staff remains the same. The 2025 Review was supported by good documentation, transparent data sharing, and a positive, open attitude that fosters trust and mutual respect. There is a strong sense of shared purpose and teamwork, creating a positive and collaborative atmosphere, including joint motivational activities.

Leadership has shown willingness to adopt recommendations and embrace innovation, with notable improvements since the 2019 Review. The genebank is globally recognized and managed by qualified curators and enthusiastic staff. Future priorities include strengthening maize curation alongside wheat, updating global strategies, and adopting modern tools to enhance efficiency. The leadership's commitment to sustainability, collaboration, and excellence positions the genebank as a cornerstone of global crop conservation and a model for innovation and impact.

- **Contribution to the global system of crop diversity conservation**

  - User engagement

User engagement in the genebank is built on structured processes, proactive outreach, and strong connections with diverse stakeholders. Distribution of germplasm is strictly for breeding and research purposes or rematriation. Requests are processed primarily through Genesys, where most users submit their applications. Internal requests are also expected to follow this system, even if compliance is not always perfect. For legal compliance, the click-and-collect process requires a PIC number, which gives a guarantee that the receiving institution will commit to the legal terms of the SMTA, and any rejected requests are justified via email. Large-scale requests require special approval when the request exceeds 100 accessions.

Rematriation cases follow similar procedures, although they do not require an SMTA. For example, the Jala maize rematriation effort involved direct collaboration between CIMMYT and local community seed banks. The genebank actively participates in events and farmer fairs to identify gaps and reconnect communities with lost varieties. In Michoacán, staff helped link local populations to accessions collected in their region, enabling seed provision. Farmers who report lost maize types are shown matching accessions from the collection, which they can request. These efforts extend to community seed banks, where CIMMYT trains trainers to strengthen local conservation capacity. In Guatemala, where collections have been lost twice, the genebank successfully restored materials, creating a strong sense of trust and partnership. This is very good and is consistent with the conservation for use mission of all genebanks.

Strategic engagement with other CGIAR genebanks also included a gap analysis across 25 crops, revealing that maize and wheat are among the best-represented crops. The genebank seeks opportunities by consulting with breeders regarding priority traits, such as unarchiving some wheat wild relatives. When the Australian genebank had only nine accessions of a requested wild wheat relative, CIMMYT directed breeders to USDA, which holds 300 accessions.

The genebank continues to strengthen the Latin American Community of Practice (CoP), which unites countries under ITPGRFA, though Mexico has yet to sign. Discussions focus on developing regional core collections of wheat and maize housed at CIMMYT, despite challenges in sharing materials from some countries. Benefit-sharing mechanisms are being promoted to encourage compliance. Complex cases, such as Agrosavia's negotiations with indigenous and Afro-descendant communities, highlight the need for culturally sensitive approaches. Belize currently contributes only eight accessions, underscoring the urgency of expanding collections from underrepresented countries at risk of losing landraces and genetic diversity.

Through structured processes, targeted outreach, and collaborative initiatives, the genebank ensures that user engagement is not only transactional but also transformative, connecting global conservation efforts with local communities, breeders, and research institutions to safeguard crop diversity for future generations. Continued promotion of genebank activities and engagement with farmers and communities with CIMMYT support should continue to be a priority.

- Partnership with NARS, other genebanks, and other stakeholders

The genebank has built strong partnerships across Latin America and the Caribbean through the Community of Practice (CoP) initiative, developed jointly with CIAT and CIP. This collaborative platform brings together 15 countries and 33 institutions, such as universities, creating a dynamic network for knowledge exchange and capacity building. Regular online meetings with NARS focus on critical topics like digital sequencing information, addressing the challenge that very few institutions have the resources to genetically characterize their collections.

Annual in-person meetings strengthen these ties, with recent gatherings in Uruguay including three site visits. Activities include gap analyses of collections, the exchange of SOPs, and discussions on core and regional core collections, ensuring harmonized practices across partners. The collaboration goes beyond sharing knowledge: it fosters active exchange and mutual support, exemplified by a WhatsApp group connecting 15 countries ready to assist each other.

This effort originated from DivSeek as a hub, complemented by CIAT's work, and was made possible by combining CIAT and CIMMYT budgets to create a sustainable platform for collaboration. By leveraging shared resources and expertise, the partnership is setting a precedent for regional and global cooperation in genetic resource conservation.

International collaborations include Honduras for in situ conservation and for alignment of drying protocols to FAO genebank standards. Partnerships with NARS, Agrosavia, SNICS, and INIFAP support regeneration and rematriation efforts, including conservation of rare races like Jala, which require nine months to produce one or two ears. Community genebanks are being strengthened through capacity-building initiatives and farmer training, even in regions affected by security challenges.

- Germplasm availability in MLS

Most of the CIMMYT collection is available through the MLS; however, germplasm availability for distribution is limited by the seed health issues.

- Lead the update and implementation of global crop conservation strategies for wheat and maize.

CIMMYT curators are already leaders within the Latin American genebanking communities. Their strong relationships with these and other genebanks should be used to update the wheat and maize Global Crop Conservation Strategies. This will further demonstrate CIMMYT's global leadership and foster additional new relationships. Opportunities lie in expanding technology use, improving workflows, updating facilities, and deploying GGCE across all operations. There is also interest in capacity building through initiatives like the Crop Trust's Genebank Academy and regional collaborations such as the LATAM CoP.

6 Next generation conservation

(e.g., Optimizing the composition of the collection; Green genebank; Automation; Digital genebank)

The genebank is advancing toward a future defined by efficiency, sustainability, and digital integration. A major step in optimizing the composition of the collection is the ongoing genetic characterization effort. Although the genotyping laboratory is not part of the genebank, it plays a critical role through DArTSeq characterization, funded by the Mexican government and involving all CIMMYT programs. This initiative also included collections from ICARDA, CIAT, CIP, and Agrosavia. As a result, 100% of the wheat collection has been genetically characterized, generating an extraordinary dataset of 25×10^9 data points. These data can now be used for allele mining to address climate change challenges, and similar work is underway for maize. Combined with geolocation and environmental data such as humidity, temperature extremes, aridity, and salinity, the genebank is positioned to conduct environmental GWAS and predictive modelling, even when precise geolocation is missing, since they also have approximate regional maps, which are a first step to address allele mining opportunities. This scale of integration, coupled with AI-driven analytics, represents a unique opportunity to link genomic insights with conservation strategies.

Technological innovations are being explored to enhance efficiency and accelerate digitalization. A Videometer lab is developing multispectral algorithms to identify accessions, reducing reliance on expert visual assessment and improving accuracy in taxonomy and descriptor analysis. While the temperature and relative humidity monitoring systems are not yet integrated into SOPs, they represent a major step toward a fully digital genebank.

Optimizing the collection also requires attention to seed health, regeneration, and agronomic management. For maize, ensuring proper nutrition and drying is essential for longevity. Budget constraints often force adjustments to SOPs, such as mixing harvests from two years when regeneration yields fewer than 75 ears, which is indeed better than continued regeneration attempts. Staggering planting dates to synchronize flowering is also a valid strategy. In some cases, like for Peruvian accessions, the lack of synchronization between male and female plants complicates regeneration. Characterization efforts increasingly rely on drones and imaging technologies, paving the way for AI-based race classification. Additional innovations include a repackaging project using kangaroo packaging and monitoring humidity inside storage jars to safeguard seed viability until the maize collection is fully repackaged.

The genebank's commitment to sustainability is reflected in its Green Genebank approach, which emphasizes energy efficiency and resource optimization. While facility upgrades, such as improving natural light in processing areas, remain pending due to long timelines and budget limitations, the integration of solar energy and workflow-aligned designs is part of the long-term vision.

Digital transformation is central to this strategy. The genebank is leveraging genomic data, AI, and predictive analytics to enhance decision-making and optimize conservation. Environmental GWAS and machine learning models will enable unprecedented insights into adaptation traits, positioning the genebank as a global leader in data-driven crop conservation. However, these advances depend on adequate staffing and budget to fully exploit the potential of genomic resources. Linking pre-breeding efforts more formally between wheat and maize programs is another priority, as wheat pre-breeding currently sits outside the Genetic Resources Program, limiting integration.

Historical efforts, such as the 2007–2010 wild relative collection in Mexico, have filled many gaps, though northern Mexico remains underrepresented. While maize is well documented, other species require targeted collection, including maize and wheat wild relatives adapted to tropical conditions in Haiti and Nicaragua. Current projects in Guatemala aim to expand collections into Belize, ensuring that underrepresented regions and species are safeguarded for future breeding and research.

By combining genomic characterization, automation, sustainability practices, and digital tools, the genebank is building a future-proof system that not only conserves diversity but also transforms it into actionable knowledge for breeding and climate resilience. This holistic approach ensures that the genebank remains at the forefront of innovation while safeguarding the genetic foundation of global food security.

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

The (draft) business plan is coherent and consistent with the possibilities team's capabilities and opportunities. The focus is on improving quality, representation, curation, and utility rather than expanding size, which is excellent.

Recent achievements include the complete genetic characterization of the wheat collection using high-throughput genotyping, enabling audits to identify duplicates and harmonize data with ICARDA. Updated cluster analyses will improve representation and guide curated subsets for targeted use. For maize, efforts prioritize OPVs adapted to stress and nutritional traits like QPM, alongside strategic acquisitions from regions facing genetic erosion. Collaborations with INIA–Peru, La Molina University, and UTEA aim to regenerate accessions locally, while the *Tripsacum* collection will undergo viability and documentation review. All acquisitions comply with ITPGRFA and phytosanitary standards.

Specialized accession panels—stress-resilient, regional diversity, and nutritional quality—will be enhanced with complete metadata to accelerate research. Archiving follows transparent protocols, retaining records in Genesys and periodically reviewing for reactivation. Cold storage capacity supports modest growth, complemented by digital inventory systems, barcoding, and RFID integration for real-time tracking. Predictive planning tools will anticipate regeneration needs based on viability trends and user demand, reducing backlogs.

Coordination between field stations, seed labs, and the Seed Health Laboratory will be strengthened to streamline post-regeneration workflows, accelerate phytosanitary clearance, and harmonize data flows.

CIMMYT has completed the design for a completely new certified genebank facility, featuring clean/dirty zone separation, optimized material movement, and modern equipment for high-throughput operations. Key outcomes include a smart vault saving up to US $500,000 annually, reducing seed distribution time by 95% (from 60 days to 3 days), and digitizing the chain of custody with RFID. The facility will also offer immersive educational experiences and prioritize staff wellbeing.

Sustainability initiatives include waste reduction, expanded solar energy coverage, and embedding environmental stewardship into SOPs and audits. Workflow optimization will continue, with innovations like Videometer Lab technology for non-destructive viability testing, real-time monitoring of drying rooms and regeneration plots via Wi-Fi or SIM-enabled sensors, and predictive analytics for resource planning. These steps, combined with genomic data integration and automation, position CIMMYT as a leader in digital, climate-smart genebank operations.

8 Overall assessment and conclusions

The CIMMYT genebank has demonstrated substantial progress toward achieving its performance objectives and is currently on track to meet established targets, with seed health being the main bottleneck. Since the 2019 Review, the genebank team has exhibited strong commitment and professionalism, fully addressing 15 of the 19 recommendations and partially implementing the remaining four. The successful integration of wheat and maize genebank operations has resulted in improved efficiency, streamlined workflows, and optimized resource allocation. This operational merger, supported by engaged leadership and dedicated staff, has strengthened the genebank’s capacity to fulfil its mandate.

Key accomplishments include a comprehensive overhaul of the wheat collection, which involved the removal of duplicated accessions and old inventories, cleaning and repackaging of materials, and implementation of barcoded labels to enhance security and processing efficiency. Safety duplication has been completed at both the National Laboratory for Genetic Resources Preservation in Fort Collins and the Global Seed Vault in Svalbard. Furthermore, the identification of an alternative regeneration site has eliminated the wheat regeneration backlog, and an efficient bulking system is now in place to speed up phytosanitary compliance.

Progress in maize collection management is evident, with approximately two-thirds of the accessions repackaged into aluminium bags. However, challenges remain regarding the cost and durability of packaging materials, and alternative suppliers are being identified to expedite completion. Maize regeneration and seed health issues persist, but ongoing efforts to identify alternative regeneration sites and implement phytosanitary measures are acknowledged.

Technological advancements have significantly improved operational efficiency. The adoption of GRIN-Global Community Edition (GGCE) and barcode systems has enhanced data accuracy and eliminated manual errors. Data curation has advanced, with an average passport data completeness index of 7.47 and the inclusion of viability and seed health data. Storage validation tests conducted in 2025 confirmed that accessions are properly documented and located as indicated in GGCE.

Infrastructure and security enhancements have also been noteworthy. The installation of sensors for real-time monitoring of temperature and humidity in storage and drying rooms represents a major improvement over previous manual checks. Vault security has been strengthened through alarm response times of less than one minute and Wi-Fi-enabled cameras for emergency monitoring. While the vaults remain secure, CIMMYT policies prohibiting locked building doors for safety reasons require that specific rooms and spaces where expensive equipment and seeds are processed be secured in compliance with institutional guidelines.

CIMMYT is making significant progress towards meeting Key Performance Indicators (Table 3). Specifically, **Target 1: Availability** has not yet been achieved due to the low number of accessions that have been health tested or confirmed free of pathogens. **Target 2: Safety duplication** is on track to be achieved pending shipment to the Fort Collins safety-duplication site upon reopening of the U.S. government. **Target 3: QMS** is achieved. **Target 4: Data availability and completeness** is achieved. **Target 5: Capacity building** is achieved.

In conclusion, the CIMMYT genebank demonstrates strong leadership, a collaborative culture, and a clear commitment to excellence. Continued efforts are recommended to complete maize repackaging, resolve regeneration and seed health challenges, and implement security measures for sensitive areas, including improvement of the processing and drying areas. Importantly, these actions should proceed without awaiting the construction of a new building. With these measures, the genebank is well-positioned to maintain its global role in genetic resource conservation and achieve its long-term performance objectives. The genebank is rightly regarded as CIMMYT's crown jewel.

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 a 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. CIMMYT was reviewed by two experts, facilitated by Nelissa Jamora and Marleen Engbers. The members of the review panel were:

- *Dr. Marise Borja, Chair of the review panel with experience in conducting genebank reviews with expertise in institutional analysis, diversity assessment, and genebank management. Director Global Regulatory Affairs at the Syntech Research Group, she has Doctorate in Genetics and Master in Bioethics. She has worked with genetic resources since 1985 in both the private and public sectors including UC Berkeley, Spanish CSIC research council, Plant Response Biotech and GAB Consulting. She was Advisor to the Spanish Ministry of Research for 9 years. Associate professor at Complutense University since 1996. Expert for the EU Commission (DG Agri, DG Environment and DG Research) since 1996 and FAO since 2001.*

- *Dr. Gayle Volk, Independent Consultant, and former Plant Physiologist with USDA National Plant Germplasm System (retired 9/2025), National Laboratory for Genetic Resources Preservation in Fort Collins, Colorado for 26 years. She has genebank management experience within USDA and co-coordinated the development of two Global Crop Conservation Strategies as well as the FAO Practical guide for the application of the Genebank Standards for Plant Genetic Resources for Food and Agriculture – Conservation through cryopreservation. She is co-coordinator of the GRIN-U.org outreach and education website and has developed and taught courses in genebank management.*

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

The 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 metrics

Indicators	Total*	Maize	Wheat
Composition			
1. Number of accessions in total	153,040	28,779	124,261
2. Number of seed accessions	153,040	28,779	124,261
3. Number of accessions in *in vitro*	0		
4. Number of accessions in cryo conservation	0		
5. Number of field bank accessions	161	161	0
6. Number of seed accessions conserved in MTS	149,995	28,612	121,383
7. Number of seed accessions conserved in LTS	151,546	28,612	122,934
Availability			
8. Number of accessions that are fully-curated	151,751	28,612	123,139
9. Number of accessions that are legally available	151,275	28,441	122,834
10. Number of accessions included in MLS	146,550	25,885	120,665
11. Number of accessions that are physically available	137,806	22,176	115,630
12. Number of accessions that are physically and legally available for immediate distribution	137,806	22,176	115,630
13. Number of accessions viability tested	149,388	28,636	120,752
14. Number of accessions with viability above 85%	146,653	27,765	118,888
15. Number of accessions health tested	37,705	8,965	28,740
16. Number of accessions that are clean and healthy	36,988	8,554	28,434
17. Number of accessions with adequate seed number	146,935	25,245	121,690
18. Number of seed accessions regenerated or multiplied in last 5 years	27,302	5,221	22,081
19. Number of samples subcultured in last 5 years (clonal)	0		
20. Number of samples rejuvenated in the field/greenhouse in last 5 years (clonal)	0		
Safety duplication			
21. Number of seed accessions safety duplicated at two locations	132,328	22,646	109,682
22. Number of seed accessions safety duplicated at Svalbard	141,906	25,927	115,979
23. Number of clonal accessions held in cryopreservation at two locations	0		
24. Number of clonal accessions held in *in vitro* at two locations	0		
25. Number of field accessions maintained in at least two locations	0		
26. Number of accessions held in *in vitro* and in field	0		
27. Number of accessions held in *in vitro* and in cryo	0		
28. Number of accessions maintained in the field and conserved in cryo	0		
Distribution			
29. Total number of accessions distributed internally in the last 5 years (within the institute)	13,504	3,154	10,350
30. Total number of accessions nationally in the last 5 years (outside the institute)	3,296	3,109	187
31. Total number of accessions distributed internationally in the last 5 years (outside the country)	12,382	4,099	8,283
32. Total number of samples distributed in the last 5 years (all recipients)	47,336	24,355	22,981
33. Total number of SMTAs sent in the last 5 years	736	521	215
Information			
34. Number of accessions with passport data available in Genesys	153,040	28,779	124,261
35. Number of accessions with characterization and/or evaluation data available in Genesys	44,398	28,759	15,639
36. Average passport data completeness index	7.47		
QMS			
37. Number of SOPs written (13=5 operations manuals, 5 process documents and 3 for quality management)	13		
38. Staff succession/management plan available and maintained (Y/N)	Y		
39. Risk management plan available and maintained (Y/N)	Y		
40. Equipment and supplies inventory available and maintained (Y/N)	Y		
Use			
41. Annual number of germplasm requests received (average in the last 5 years)	187		
42. Regular feedback from genebank users (Y/N)	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 but would improve the efficiency/sustainability of operations
2 = Major issues or gaps identified, likely to impact genebank/QMS standards and would reduce efficiency/sustainability of operations
3 = Critical issues or gaps identified, impacts genebank/QMS standards and efficiency/sustainability of operations
n/a = Not applicable, not assessed

Area, Themes	Factors to consider	*Score
A. Genebank overview		
Staff management		
Adequacy of staffing	1. The genebank has adequate skilled staff to perform key genebank operations. Identify gaps or shortages in staffing.	1
Succession planning	2. The genebank takes action to mitigate adverse impacts of staff loss from staff movement (e.g., resignation, retirement, promotion).	2
Capacity development	3. The genebank has a clear understanding of capacity building needs. [Identify short- and long-term capacity development needs.]	0
Composition of the collection		
Uniqueness and importance	4. The genebank conserves unique and valuable crop collections, including Annex 1 crops (consider crop importance to national country and to global conservation and use). [Identify unique and valuable crop collections that are at risk; check for redundancies or gaps; Determine if particular crops should be prioritized.]	1
Conservation forms	5. The genebank has multiple forms of conservation (seed, *in vitro*, field, greenhouse, DNA, cryo) corresponding to different crop types in the collection. [Confirm the different conservation forms available in the genebank.]	0
KPIs		
KPI: Collection size	6. The genebank has information/trends on the size and composition of its collection. Check plans and capacity for expansion of collection size.	0
KPI: Availability	7. The genebank has information/trends on the number of accessions that are available for immediate distribution. Determine how "availability" is calculated and if availability has increased or decreased with time.	0
KPI: Data availability	8. The genebank has information on access, availability, and sharing of germplasm related data through their websites and/or Genesys. Identify issues in data sharing.	0
KPI: Data completeness	9. The genebank uses Multi-Crop Passport Descriptors (MCPD) and/or other descriptor lists. Identify issues in the use of MCPD and/or other descriptor lists.	0
Supplies, equipment, facilities & infrastructure		
Infrastructure	10. The storage chambers (LTS and MTS) are fit for purpose (i.e., well suited) for their intended use.	0
	11. The seed processing and packing areas are fit for purpose (i.e., well suited) for their intended use.	3
	12. The drying room/chamber is fit for purpose (i.e., well suited) for its intended use.	3
	13. The seed cleaning area (internal/external) is fit for purpose (i.e., well suited) for its intended use.	3
	14. The viability testing area or laboratory is fit for purpose (i.e., well suited) for its intended use.	0
	15. For clonal crops, the *in vitro* storage chambers are fit for purpose (i.e., well suited) for their intended use.	NA
	16. Environmental records (light, temp, RH) for storage chambers and drying rooms are maintained and periodically monitored.	0
	17. The genebank facilities have safety measures in place (restricted access, cameras, etc.).	3
	18. The genebank has a replacement plan for infrastructure and equipment.	0
Equipment	19. The genebank maintains a list/inventory of key equipment (computers, balances, threshers, etc.).	0
	20. The number, type and condition of the equipment is adequate to carry out activities in the genebank.	1
	21. Maintenance, calibration and replacement is periodically performed on key equipment.	0
	22. The genebank uses barcoding in the management of genebank operations.	0
Supplies	23. The genebank maintains a list/ inventory of key supplies (jars, envelopes, boxes, etc.).	0
	24. The quantity and types of supplies are adequate to carry out activities in the genebank.	0
Field stations and greenhouses	25. The field station(s) is fit for purpose (i.e., well suited) for its intended use. Identify any deficiencies or oversights in field station management.	2
	26. The greenhouse is fit for purpose (i.e., well suited) for its intended use. Identify any deficiencies or oversights in management.	0
Overall assessment	27. Provide an overall assessment of the adequacy of genebank supplies, equipment, facilities & infrastructure. Note any strengths or weaknesses or gaps.	2
B. Genebank operations		
1 Acquisition		
1 Adequacy of procedures	28. The genebank assesses viability and phytosanitary health upon reception of new material.	0
	29. The genebank has post-entry quarantine rules for new materials, prior to introduction into the genebank collection.	0
2 Information management	30. The genebank has a protocol for assigning unique identifiers and accession numbers for new materials, prior to introduction into the genebank collection.	0
	31. Data and information required for and generated during the acquisition procedure is recorded and entered into the documentation system.	0
3 SOP	32. The genebank has a written acquisition procedure/protocol/policy.	0
Overall assessment	33. Provide an overall assessment of the adequacy of the procedure. Note any strengths or weaknesses or gaps.	0
2 Conservation:	**Seed processing, storage, and viability testing**	

Area, Themes	Factors to consider	*Score
1 Adequacy of procedures	34. The genebank follows an established protocol for seed cleaning.	0
	35. The genebank follows an established protocol for seed drying and testing of moisture content.	0
	36. The genebank follows an established protocol for packing samples in containers or envelopes.	1
	37. The genebank follows an established protocol to maintain germplasm health prior to storage.	0
	38. The genebank periodically conducts viability testing.	0
	39. 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.	2
2 Information management	40. Samples are properly labeled.	0
	41. Data and information required for and generated during the conservation procedure is recorded and entered into the documentation system.	0
3 SOP	42. The genebank has a written conservation procedure/protocol/policy.	0
KPI: Viability and health testing rates	43. The genebank has information on the viability/vigor and health of the collection. Check the number of viability/health tests done annually, % of accessions viability/health tested.	0
Overall assessment	44. Provide an overall assessment of the adequacy of the procedure. [Note any strengths or weaknesses or gaps.]	1
3 *In vitro* conservation		
1 Adequacy of procedures	45. Light and temperature regimes are adequate for *in vitro* culture.	NA
	46. The genebank regularly monitors the quality of the *in vitro* culture in slow-growth storage, maintenance of long-term genetic stability and possible contamination.	NA
2 Information management	47. Samples are properly labeled.	NA
	48. Data and information required for and generated during the *in vitro* conservation procedure is recorded and entered into the documentation system.	NA
3 SOP	49. The genebank has a written *in vitro* conservation procedure/protocol/policy.	NA
Overall assessment	50. Provide an overall assessment of the adequacy of the procedure. [Note any strengths or weaknesses or gaps.]	NA
4 Regeneration and Characterization		
1 Adequacy of procedures	51. Regeneration practices are appropriate to ensure that genetic integrity is maintained. (regarding origin of seed, number of seeds to be planted and harvested, and pollination control).	0
	52. Regeneration practices are appropriate to ensure that germplasm health is maintained.	3
	53. Field sites used are appropriate for the needs of the crops conserved.	2
	54. Field management (land preparation, irrigation, rouging, agrochemical applications) are adequate for regeneration and characterization of genebank accessions.	2
	55. 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).	0
2 Information management	56. Characterization data is publicly available, or available upon request.	0
	57. Samples are properly labeled.	0
	58. Data and information required for and generated during regeneration and characterization is recorded and entered into the documentation system.	0
3 SOP	59. The genebank has a written regeneration and characterization procedure/protocol/policy.	0
KPI: Regeneration and characterization rates	60. The genebank has information on the number of samples regenerated and characterized annually. [Check whether the annual rates are justifiable given the crop and status of the collection.]	0
Overall assessment	61. Provide an overall assessment of the adequacy of the procedure. [Note any strengths or weaknesses or gaps.]	2
5 Distribution		
1 Adequacy of procedures	62. Prior to distribution, the seed quantity, viability, and phytosanitary status of the samples to be distributed is known/checked.	0
	63. 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
	64. Samples are distributed in compliance with national laws and relevant international treaties and conventions. [Check the use of transfer agreements.]	0
2 Information management	65. Samples are properly labeled.	0
	66. Data and information required for and generated from germplasm request to distribution is recorded and entered into the documentation system is updated in timely manner.	0
	67. If SMTAs are used in distribution, SMTAs are periodically reported to the Secretariat of the ITPGRFA to fulfill the SMTA provider's reporting obligations.	0
3 SOP	68. The genebank has a written distribution procedure/protocol/policy.	0
KPI: Distribution	69. The genebank has information/trends on the distribution of its accessions. Check the number of accessions distributed annually in the last decade, extent and scope of distribution (national, vs international, key genebank users and most distributed crops and/or accessions.	0
KPI: User satisfaction	70. The genebank requests feedback from users to improve the delivery of genebank service. [Check recent examples of feedback from users.]	0
Overall assessment	71. Provide an overall assessment of the adequacy of the procedure. Note any strengths or weaknesses or gaps.	0
6 Safety duplication		
1 Adequacy of procedures	72. Safety duplicate samples are stored in another location, under the same or better conditions than those in the original genebank. [Identify safety duplication sites.]	0
	73. Safety duplicate samples are stored internationally (including Svalbard), for second-level safety duplication. [Identify safety duplication sites.]	0
	74. The size of safety duplicated samples is sufficient to conduct at least three regenerations.	2
2 Information management	75. Samples are properly labeled.	0
	76. Data and information required for and generated during safety duplication is recorded and entered into the documentation system.	0
3 SOP	77. The genebank has a written safety duplication procedure/protocol.	0
KPI: Safety duplication	78. The genebank has information/trends on the percent of the collection that is safety duplicated in one or more locations or geographically distant sites. Check the number of accessions safety duplicated. Confirm willingness and capacity to safety duplicate materials to Svalbard.	0

Area, Themes	Factors to consider	*Score
Overall assessment	79. Provide an overall assessment of the adequacy of the procedure. Note any strengths or weaknesses or gaps.	1
7 Field genebank		
1 Adequacy of procedures	80. The genebank follows an established protocol for field conservation, and regularly monitors the quality of plants.	3
2 Information management	81. Samples are properly labeled.	0
	82. Data and information required for and generated in field genebank is recorded and entered into the documentation system.	0
3 SOP	83. The genebank has a written field genebank conservation procedure/protocol/policy.	3
Overall assessment	84. Provide an overall assessment of the adequacy of the procedure. Note any strengths or weaknesses or gaps.	3
C. Genebank management		
QMS	85. The genebank implements a system that leads to improvement over time (if applicable, establish which genebank standards and best practices are implemented (awareness of FAO Genebank Standards and others).	0
Information management	86. Information management system is available and used in the management and monitoring of the collection.	0
	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.	0
Phytosanitary procedures	89. The genebank (or its health unit) maintains and updates a list of quarantine pests and diseases and monitors and manages contamination incidents.	0
	90. Phytosanitary procedures are followed in germplasm transfers (import and export).	0
Risk management	91. The genebank can provide evidence of periodic risk analysis, prevention, response and mitigation (e.g., natural disasters, human-caused threats, incidences of pests, diseases, cyber security and biological threats (pandemics). [Identify recent risks encountered and actions taken.]	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 amounts of time). [Identify any backlogs or bottlenecks.]	2
Overall capacity	93. The genebank's overall capacity to conserve seeds, clonal crops and field collections is adequate.	1
D. Enabling environment		
Finance	94. The institution has 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). Determine how staff salaries and annual routine operations are supported.	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 Plant Treaty country focal point).	0
Leadership	98. Commitment to quality of leadership, staffing, and vision.	0
External linkages to users	99. The genebank actively 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 NARS, other national genebanks or other partners on crop conservation-related activities.	0

Annex 4 Comments on CIMMYT Operations and Procedures Manuals.

All documents: Add an abbreviations page to each.
Add Operations Manual for field/screenhouse collection of *Tripsacum.*
Ideally use CG templates for Manuals/SOPs
List equipment models and manufacturers.

Operations Manual Introductions Process
MAN-GB-IN-01
Add text describing the criteria by which new accessions are accepted into the genebank (fill gaps, novel elite cultivars, landraces, etc.).
Determine if all the listed forms are necessary or if processes can be automated.
Add more details about black box agreements, payments, criteria to qualify, etc.
Include the collection of 100 seed weight data.
List desired quantities for receipt (it's in other SOPs)
Also take photos of each received seedlot.
Also follow up with provider to acquire missing passport data.
If it arrives with an SMTA, ensure it's recorded in GGCE.
When does seed health testing occur? Presumably before it arrives at the genebank. Mention this.

Seed Conditioning Operations Manual
MAN-GB-AC-01
Minimum acceptable quantity for wheat (doesn't match other documents):
No backups 120 g
One site backup 135 g
Two site backup 150 g
Determine if all the listed forms are necessary or if processes can be automated.
Clean seed sorting equipment after each sample.
Conditioning operations manual doesn't state to check wheat MC upon arrival, yet we were told it's often within the acceptable moisture content range. Consider putting grains in mesh bags to decrease drying time.
Update information about sensors in drying rooms, so manual room condition data don't have to be recorded.
Describe that 75 ears are used for balanced samples
Provide a diagram to better describe the maize ear sampling process.
Describe what to do with the non-conforming output seeds
100 seed weight data for maize and wheat
Do you have estimated MC? Or can this content be removed from the manual?
Process seeds in humidity controlled room so they don't regain moisture during processing (warming to room temperature for moisture content data collection, etc.).
Is the moisture content data collection information complete in the manual? It may be a different instrument than was demonstrated.
Calculate moisture content curves to predict how long it will take to adjust to the appropriate level so excessive moisture content data aren't collected. If seed drying is slow, then use different containers and shelving conditions to increase air flow.
Explain that 8.1.2 lists the team who is responsible for equipment calibration each year.
Make sure seed health testing preparation is well described. List what diseases are tested (because there aren't seed health SOPs)

Conservation

PRO-GB-CO-01
Wheat minimum quantity (confirm numbers)
90 g no backup
105 g backup at one site
120 g backup at two sites
Include a recency indicator with respect to viability testing
Include health testing here, if it's not in the Conditioning Manual
Incorporate more automated processes and fewer forms/emails.
VI.IV-- #6-8 are in Spanish

Operation Manual for Conservation
MAN-GB-CO-01
Is most original seed sample also kept in LTS?
Please clarify that safety-duplicate samples are pathogen tested
Collect 100 seed weight data for wheat
Increase number of seeds for maize safety duplication for 3 regenerations
When are maize samples prepared for CNRG?
Add details about when temporary storage is performed and the associated agreements/costs
Chapter 4. Viability testing
Is viability performed according to ISTA standards?
Add a statement about the expected longevity of healthy seed in MTS and LTS storage.
4.3.2.2 Describe the rules.
4.3.3.7 States conditions for viability incubation, so 4.4.1 isn't necessary.
4.5.1.1 Describe how many petri dishes (replicates) are used for teosinte
4.5.2 Use seed placement diagrams on the counter (add image)
Reassess viability testing intervals. LTS doesn't need to be checked as often as MTS. MTS monitoring times can be adjusted (with scientific data support) according to expected seed longevity.
6.5 Include information about the number of seeds per packet for regeneration
7.3.3 Update diagrams to include foil packets in storage
Are balanced maize samples in LTS?
Describe the need to save an extra seed health packet for one year in case seed health verification is needed.

Regeneration Operational Manual
MAN-GB-RE-01
Include an illustration to describe field arrangements.
Clarify when Standard and HIT plot sowing are used.
Describe how many seeds are sown for each plot/crop.
Describe the field site locations that are used for each crop, and which accession types are regenerated at those locations.
7.7 Add more information about field thresher for wheat, with cleaning between plots, etc.
Add information about crop rotation
Add more information about how fields are managed and interactions with field managers
Describe that balanced samples are used for maize regeneration, and how many packets of balanced samples are used for each regeneration.
Describe where the standards are from that are used for each crop.
Describe how staff are trained in the characterization activities
Why are only 3 diseases listed for 10.14?
Include color chart for color descriptors
Describe where barcodes are used for maize descriptor collection in the lab

Describe how materials are kept for the following year if there are inadequate quantities.

Distribution Process Operational Manual
MAN-GB-DI-01
2.4 in Spanish
Ensure that all the described steps are currently performed.
Describe email interactions to obtain import permit, to determine which SMTA type to send, etc.
Describe how easySMTA is not used for CIMMYT researchers unless the accession was originally received with an SMTA.
Include list of everything that is included in the shipping box for domestic and international shipments.
Include information about follow ups regarding receipt of seeds and 2 year follow up of use.

Process Management for the Genebank
POL-GB-01
Include content from sections 5 & 6. Acquisition of Germplasm in the Acquisition Operations Manual.
7. Adjust LTS to -18C
7 & 8. Include content from Conservation Conditions in Conservation Operations Manual
9. Make sure Distribution is aligned with Distribution Operations Manual.
11. Describe number of seeds in safety duplication samples.
Describe what types of organizations can have blackbox agreements with CIMMYT.
12.5. There is likely an error in this statement.
12.8 Confirm planting quantities for wheat and maize and make sure they align with the Regeneration Operations Manual.
Include seed health and field sites for regeneration activities.
Include balanced sample information for maize.
Describe when GMO testing is performed (in Process Management and any relevant Operations Manuals).
Include monitoring interval information from Process Management in the Conservation Operations Manual.
Include the need for an import permit for distribution.

Quality Management Manual
MC-BG-01
5.2. Revise Quality Policy that states … "to be shared with any requesting party."
Update names to include Laura Lewis.
Update "BG" to "GB" in text.
Include information about staff training opportunities and activities (GGCE, etc.).

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