Table 1c. Potential risks and management options for seed banks.

Activity	Risk Sources/Indicators	Risk/Consequence	Action Plan		
			ACQUISITION		
Collecting	Narrow genetic variability and large gaps in germplasm collection	Failure to capture diversity in field	Send Center genebank personnel to take the lead in joint collecting missions with national programs. Conduct training of collectors in partner countries. Maintain and hire a pool of expert collectors.		Analyse collection for un-represented regions and conduct gap-filling collecting.
	Wide variability in flowering time and high shattering of wild types	Failure to capture diversity in field			Collect large amount of original sample.
	Low seed amount of new acquisitions	Genetic drift			Collect large amount of original sample.
	Untrained personnel in collecting and documentation	Failure to capture diversity in field and document important information	Send Center genebank personnel to take the lead in joint collecting missions with national programs. Conduct training of collectors in partner countries. Maintain and hire a pool of expert collectors.		
	Misidentification of germplasm	Misleading information	Include taxonomists during collecting.		
	Lack of simple collection protocol and documentation forms	Failure to capture diversity in field			Develop simple collecting procedures and forms.
	Agricultural intensification, replacement of traditional varieties with modern ones, urbanization, land use change, and climatic events	Loss of germplasm in habitat			Prioritize affected and high-diversity areas for collecting germplasm
	Strict country and international laws on access and use of germplasm	Poor access and use of germplasm in unexplored areas			Secure a Germplasm Acquisition Agreement between donor country and Centre to manage accessions under FAO conditions.
	Breach of country and international treaties	Legal consequences. Damaged reputation and relationship	Training of all institute staff on intenationally agreed protocols, in consultation with Genebank and other Center authorities.		Follow national procedures of obtaining collecting permits, under relevant international agreements. • Collect in partnership with local PGR people.
	Ambiguous position of countries regarding international treaties	Poor access and use of germplasm in unexplored areas			Foster goodwill through PGR, pre-breeding, breeding and Treaty-related training-workshops, and incentivize donation.
Donation	Received foreign materials carry pests and diseases	Introduction of pest and diseases to host country			Strictly observe quarantine regulations. Keep from main storage areas until fully checked and decontaminated. Subject to hot water treatment. Grow and regenerate materials in screenhouse or away from large crop production areas of local
	Limited seed testing capability	Restricts international germplasm exchange		Develop testing and handling capability for pests and diseases of international importance.	
	Reluctance to share germplasm due to IP rights	Restricts international germplasm exchange		Conduct training on benefits and limitations of IP rights.	
	Working collections not duplicated in major genebanks	Failure to capture elite germplasm			Proactively conserve breeding materials.
			CONSERVATION		
Registration	Unverified passport and other data submitted	Incorrect or unreliable passport data, and subsequent reports			Verify passport information with donor.
	Received materials have low viability	Loss of germplasm			Obtain large amount of samples and handle properly.
Sample Processing	Culling of perceived offtypes that are true components of original sample	Loss of genetic integrity	Assign handling of highly heterogenous samples to well-trained personnel.		Prepare seed file, panicle file and herbarium specimen of heterogenous samples. Keep putative offtypes until verified with new harvest.
	Non-removal of damaged seeds hence reducing true viable sample size	Drift and loss of genetic integrity from presence of unremoved damaged/weak seeds	Assign well-trained staff in seed cleaning		Strictly select for healthy seeds Include seed health testing during regular storage viability tests.
	Inefficient fumigation	Drift and loss of genetic integrity from insect damage	Assign well-trained staff in seed processing		Apply fumigation at most effective doses. Include seed health testing during regular storage viability tests.
	Lack of proper disposal procedures for contaminated plant materials	Dissemination of pests and diseases to new areas.			Develop and enforce proper disposal procedures for contaminated plant materials.
	Mixture from unclean mechanical threshers and selection of hardy grains resistant to mechanical threshers	Loss of genetic integrity		If mechanical thresher is necessary, thoroughly clean equipment and collecting tray between samples.	Thresh and clean samples manually, and clean work table between samples.

Activity	Risk Sources/Indicators	Risk/Consequence	Action Plan		
Storage	Misplacement of packets back into storage tray during briefings to visitors	Loss or misplacement of germplasm	Restrict germplasm access to authorized staff.		Conduct regular and independent verification of location of accession, and update it on computerized database system. Make packet and
	Underestimate of critical sample size	Loss of genetic integrity			Store excess base set stock (1500-6000 seeds) with due regard to expected decline in viability during storage.
	Ineffective packaging material and method permeable to moisture, pest or pathogen	Reduction or loss of viability		Ensure sealing apparatus is working properly, and packaging area and technique are aseptic.	Use industry-standard packaging material and method that is impermeable to moisture, pest or pathogen.
	Safety duplication site is vulnerable to natural calamities	Inaccessible or loss of safety duplication		Full back-up in NCGRP, Fort Collins, Colorado.	
	Changing policies, financial and technical capabilities of governments hosting safety duplication	Inaccessible or loss of safety duplication		Secondary full back-up in Svalbard, Norway. Partial back-up in another CGIAR center. Prepare a pull-out scheme in the event of instability in host country.	
Testing	Human error in taking and encoding weight readings	Incorrect moisture content data	Assign well-trained staff		Computerize MC determination based on weight readings from two .
	Defective weighing apparatus	Incorrect moisture content data		Quarterly calibrate weighing balance.	
	Inefficient conduct of viability test and encoding	Overdue/backlog in viability test	Plan in advance and hire properly trained technicians and encoders.		Closely monitor and follow viability testing schedule
	Human error in viability evaluation.	Incorrect viability score	Assign staff that are well trained on ISTA standards.		Determine viability from two replicates.
	Dormancy	Incorrect viability score			Break dormancy. Optimize methods to break dormancy of recalcitrant types and wild species.
	Unsuitable viability testing procedure for special types of germplasm	Incorrect viability score			Request appropriate growing procedure from donor. Improve germination of problematic seed types.
	Inappropriate viability testing interval	Loss of viability			Establish viability testing intervals for different seed types.
	Human error in seed health evaluation.	Pest incidence undetected	Assign staff that are well trained in International Seed Testing Association (ISTA) and US National Seed Health System protocols in seed health testing. Engage Center pathologists and		Determine seed health from two replicates.
	Improper pest screening methods	Pest damage			Comply with quality standards held by center and/or country regulations. Develop improved methods to minimize errors in seed health laboratory techniques for detection of pathogens.
	Defective pest screening equipment	Pest damage		Periodically inspect pathology labs and calibrate equipment.	
	Untrained personnel in transgene detection	Loss of genetic integrity of other accessions	Conduct regular training of staff in transgenic detection.		
	Lack or improper determination of transgene presence	Inaccurate or wrong information regarding transgene presence			Use industry-standard transgene detection systems.
	Inadvertent spread of transgene in the collection	Loss of genetic integrity of other accessions	Designate a separate group of personnel for handling transgenic materials.	Designate a separate processing and storage rooms for handling and conserving transgenic materials. Assign experimental area for transgenics away from seed multiplication plots.	During registration, require a special declaration that seed samples contain no transgenes. Follow host country and center biosafety protocols to minimize accidental transfer of transgenes to non-transgenic accessions.
Regeneration	Poor field plot management	Loss of genetic integrity		Use standard large plot sizes to ensure minimal drift.	Follow standard procedures for plot management ensuring that at least 100 plants can be grown to maturity.
	Misidentification of accessions	Loss of germplasm	Assign multiple staff in seed preparation, labelling, seed distribution in seed bed, and seedling distribution in field plots.		Double check seed and seedling labels against planting plant before and after distribution in seed bed and field plots.
	Mis-roguing of true components of original germplasm	Loss of genetic integrity	Assign handling of highly heterogenous samples to well-trained personnel.		Separate regeneration of highly heterogenous samples based on seed characteristisc of original samples.
	Differential pollen productivity of subtypes in highly heterogenous samples.	Loss of genetic integrity			Seperately harvest seeds from the different subtypes of the accession and pool them proportionally to constitute the sample for storage.
	Cross pollination from other germplasm	Loss of genetic integrity		Set up regeneration of wild species inside a secure screenhouse. Consider installing pollen barriers in screenhouse. In the field, prevent pollination by alien pollen through proper isolation.	Use 30 cm x 30 cm spacing for photosensitive and high tillering accessions, and new materials. Intersperse plots with different species. If applicable, bag seed heads before pollen shedding. Use field plot layout that avoids potential risk of
	Suboptimal pollination	Loss of genetic integrity		Provide pollination cages if necessary.	Use relevant pollinators to ensure pollination, minimize differential contribution of male gametes by artificial pollination, and ensure appropriate female-male pairing by isolation, manual pollination, etc.

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	Poor quality of harvest for storage	Loss of genetic integrity			Harvest seeds at physiological maturity. Slow dry and blow seed before and after drying to remove stubble and unfilled and light grains.
	Different regeneration environment from the site of origin	Genetic shift or loss of genetic integrity		Review geographical origin of germplasm and carry out regeneration in the same or similar environment or in controlled environments (e.g. greenhouses, screen cages, etc.) that meet the environmental requirements of the germplasm.	Grow different species under their optimal light requirements.
	Inappropriate location of genebank for regeneration of photoperiod-sensitive materials	Failure to produce new seeds			Grow wild species and photoperiod-sensitive accessions during wet season.
	Escape of non-native species into environment	Invasion of host habitat	Regulate access to screenhouse and staff should change working clothes to minimize dispersal of seeds when they leave.	Restrict growing of wild species in pots with no holes inside a contained screenhouse with fine-mesh screens on all drainage canals.	After harvest, incinerate all remaining materials including the soil.
	Endemic diseases from adjacent production areas	Loss of germplasm		Conduct regeneration in isolated areas away from production farms.	
	Unavailability of pesticides to control major insect pests due to strict regulations	Loss of germplasm			
	Low germination of germplasm due to strong dormancy	Loss of germplasm			Conduct research on the physiology of seed dormancy and methods to break dormancy. Gather and integrate traditional knowledge for optimal regeneration of landraces and primitive.
Characterization and Evaluation	Inefficient and erroneous data gathering and encoding	Backlog and inaccurate characterization data	Assign staff with adequate training in characterization following international standards.	Provide digital hand-held encoder.	Independently verify encoded data. Automate computing, updating and reporting of characterization data in database.
	Descriptors that have no clear-cut correspondence to current international standard descriptors	No or limited usefulness of characterization data			Use updated descriptors and provide references for all measurements and classifications.
	Limited text-based description	Incomplete and inaccurate morphological description			Include images (600-800 pixels) of key plant parts accompanied with standard color guide eg. Mansell colors.
	Lack of diversity assessment of collection	Unknown level of breadth, duplication and gaps in collection, and conservation of unnecessary duplicates			Conduct molecular profiling and diversity analysis
DISTRIBUTION					
Policies	Lack of knowledge or negligence on seed exchange Protocol and International Treaty	Distribution without accompanying MTA. Inadvertent distribution of restricted germplasm (e.g. Non-MLS materials). Wrong information on the exchange status (MLS) of it	Conduct regular update on international agreements concerning germplasm exchange.		Implement a clearance sheet for germplasm distribution ensuring appropriate MTA and other documents and approval of personnel concerned are obtained before release.
	Recipients of "designated" germplasm or "non-designated" germplasm attempt to claim IP rights over the germplasm	Restrictions on future access and use of germplasm			Distribute accessions under a standard FAO-CGIAR MTA for "designated" germplasm, and for Center-created "non-designated" material developed in collaboration with FAO and other CGIAR Center, with a clause on the right of the Center to take legal action in case of violation of the MTA, upon recipient's agreement to MTA conditions.
	Non-compliance with phytosanitary regulations	Germplasm distributed from genebank carry diseases or pest contamination.			Seed Health Unit tests materials for bacterial and fungal diseases according to the phytosanitary standards of the importing country.
Seed Preparation	Misclassification and wrong characterization and seed stocks data	Delayed identification and preparation of requested germplasm	Conduct regular training on seed characterization.		Check characterization data. Include evaluation data that relate to needs of different users.
	Inefficient and slow processing of requests for samples.	Dissatisfied recipients of germplasm	Dedicate personnel to serving seed requests.		Keep files of relevant country and international quarantine documents .
	Errors in preparing or labeling samples	Wrong germplasm distributed by the genebank			Adopt barcoding and closely adhere to seed distribution protocol.
	Insufficient seed stock for distribution	Delay in serving seed request			Keep a minimum of 1,500-2,000 seeds per accession in the active collection. Incorporate alerts in the computerized seed stock control system for low inventory. Keep plenty of popular genetic stocks and RILs in the active set as well as their DNA samples if available.
Dispatch	Germplasm distributed with low viability	Dissatisfied recipients of germplasm			Conduct research on nature of dormancy and methods to break dormancy. Include a protocol on how to grow the particular material in every shipment, including breaking dormancy methods.
	Loss of documentation	Loss of important information about germplasm			Include copies of documentation inside shipping boxes.
	Unfavorable conditions during transport	Delay in delivery , reduction of viability or loss of materials			Use packing materials that can withstand unfavorable conditions. Choose express delivery and under dry-ice if available with reliable shipping services and tracking system.

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INFORMATION MANAGEMENT AND DISSEMINATION					
Labelling	Fading of labels and mislabelling of new bags and other containers for the germplasm accession	Wrong information on germplasm identity and inventory			Place fade-resistant, computer-generated labels and barcodes inside and outside all containers. Scan barcode labels twice on seeds and trays to prevent miscans, and then physically count entries on trays.
	Misplacement of labels as seeds are laid out for drying	Loss of accessions	Assign handling to well trained personnel. Place labels carefully under the seeds to minimize errors.		
Data Handling	Inefficient recording and database management	Backlog and inaccurate characterization data			Use GRU Database System and submit new data to SINGER every month. Bind hard copies of data in books.
	Mishandling of information and disorganized data sets (e.g. information system, field/ lab observation)	Loss or inaccessibility of information			Use GRU Database System and archive original data sheets. Integrate genebank operations, distribution records, and seed exchange policy databases.
	Improper recording of moisture content, seed inventory, viability, storage location, and characterization data.	Inaccurate or wrong information			Independently verify encoded data. Automate computing, updating and reporting of moisture content, seed inventory, viability, storage location, and characterization data in database. Provide decision-making tools in the database for various genebanking operations.
Back-up	Lack of secure back-up	Loss of genebank data		Transfer new data on CD or tape in two central databases in separate buildings. Store also in secure, passport-regulated cyberspace.	Produce photocopy and electronic copy of original data sheets. Use automatic back-up after each session in workstation. Make daily incremental back-ups and weakly full back-ups.
Data Quality	Inaccurate location of collecting sites	Misrepresentation of ecogeographic distribution			Use GIS in collecting for easy integration in the global database system.
	Inadequate information about important traits of accessions.	Low interest and utilization of germplasm			Collect data on important traits. Include desirable information from various sources.
	Human error in data gathering	Erroneous data		Use hand-held pocket PCs in field data gathering.	Check data integrity with SQL commands to catch out-of-line data.
	Important data and information remain in unuseful form.	Low level of utilization of germplasm and information.			Disseminate relevant information about germplasm through germplasm catalogs, newsletters, journals, bulletins, and operation manuals in print and cyber media.
Data Sharing	Slow availability of evaluation data for international users	Low interest and utilization of germplasm		Computerize and harmonize database with global system.	Immediately submit evaluation data into international databases.
	Limited ICT capability; server, network and IT related problems	Lack or poor accessibility of germplasm and important data to potential users	Engage a competent data curator to document decades of evaluation data in a centralized database system.	Use stable software and hardware and engage full technical support from Information Technology Unit. Change computers every 5 years. Upgrade memory and operating system	Regulate software installation and downloading. Restrict use of computer to authorized personnel.
	Malfunctioning equipment, hardware and software problems, and power interruption	Failure to update data by genebank staff and damage to computerized database system		Install redundant UPS units and hot-swappable battery packages. Enforce automatic start-up of generator within 30 seconds. Use alternating 2 power-supplies connected to the same server.	Enable immediate notification of 2 staff at work and home phones in case of database-related problems. Back up data weekly to 2 tapes/CDs, 1 kept in Center, the other in staff's home for 1 year and later in the international data hub.
INFRASTRUCTURE/PHYSICAL FACILITY					
Functionality	Storage conditions at genebank not suitable (temperature, humidity, light conditions, exposure to contaminating organisms, pests)	Reduction or loss of viability		Install an alarm system for open doors, and temperature/ humidity changes in the processing and storage areas.	Regularly check and maintain cooling units and dehumidifiers.
	Poor organization of storage trays, shelves and compartments	Loss or misplacement of germplasm		Rationalize arrangement of storage trays, shelves, and compartments.	Develop a simple labeling system for the storage space units. Conduct regular and independent verification of location of accession, and update it on computerized database system.
	Deterioration of facilities and equipment	Reduction or loss of seed viability		Pursue continual upgrading and expansion of field and laboratory equipment, etc.	
	Cold room malfunction	Reduction or loss of seed viability		Place hygrothermographs that are connected to back-up power supply and alarm system. Provide the rooms with multiple compressors and dehumidifiers that are programmed for alternate operation.	
Security	Power supply cut-off	Reduction or loss of viability		Install, regularly check, and maintain an emergency electrical generator for back-up power to the storage rooms, essential genebank lighting, monitoring devices, and access locks during electrical power failures.	

Activity	Risk Sources/Indicators	Risk/Consequence	Action Plan		
	Theft or vandalism	Loss of germplasm		Place the building under 24-hr perimeter security surveillance. Link the alarm system by optical fiber with security office and police. Install double locks in sensitive areas and closed-circuit camera monitoring by guards. Install sensors for door contacts, glass breaks and unusual motion outside work hours.	Restrict access to genebank facilitites to authorized personnel with assigned badge and PIN code for access. Conduct background check on personnel who will use facility. Regularly brief security guards on the safety and security protocols of the genebanks.
	Environmental risks/weather elements, earthquakes, other catastrophic events (civil war,…), and fire	Reduction or loss of viability	Assign personnel from genebank unit and security office for 24/7 watch of the facility.	Design and construct building according to safety, environmental and artillery protection, and earthquake proof standards. Install fire and gas alarm systems. Provide fire isolation doors, fire extinguishers, and doors than can open from inside cold chambers to prevent personnel getting trapped.	Conduct periodic maintenance checks and inspect genebank during heavy rains and earthquakes for leaks in the cold and drying rooms. Periodically check fire safety checks.
PERSONNEL AND SUPPORT SERVICES					
Personnel	Inadequate complement of technical staff	Inefficient operations	Hire at least one highly qualified technician each to manage seed viability test, seed drying and moisture test, seed health test, characterization and regeneration, data management, and seed distribution. For an active collection with research and development needs, hire a scientist to take charge of planning, research and analysis, a technician to take charge of daily operation of the laboratory, laboratory assistants for seed cleaning, seed processing and seed packaging, and field workers for seeding, field-layout, screenhouse and field maintenance and harvesting.		
	Incompetent staff	Inefficient operations	Hire researchers with advanced degrees in plant physiology/genetics. Hire laboratory technicians with a background in plant science. Hire laboratory assistants with training in basic botany. Provide 1-2 weeks intensive on-site training for each new staff member on standardized laboratory and field protocols, followed by close supervision for as long as needed.		
Working environment	Routine tasks and uncompetitive remuneration	Fast staff turnover	Rotate work assignments as much as possible or assigning special projects to technicians. Educate workers on the mission of the facility to boost morale and establish a research-oriented		
	Exposure to occupational hazards	Reduced manpower capability			Protect staff members from pesticide exposure, for example, by spraying during weekends.
Support Services	Inefficient human resources services	Delayed hiring of required manpower			Review and streamline hiring/recruitment protocol.
	Inefficient purchasing and repair services	Delayed delivery/repair of required supplies and equipment			Review purchasing protocol to speed up requisition process. Keep spare parts for crucial pieces of equipment in stock (specially the ones not locally available), as a risk mitigation procedure (filters, batteries, lamps, fuses, sealing devices)
Financial	High cost of genebank operations	Loss of donor and user support			Closely follow and seize funding opportunities with The Global Crop Diversity Trust and other funding donors.