Table 1. Potential risks and management options for clonal banks.

Activity	Risk Sources/Indicators	Risk/Consequence	Action Plan			Contingency	Responsible Unit
			People	Facility	Procedure		
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.	Send a follow-up collecting mission.	GRU
	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.			Based on level of risk and of diversity in collecting site to target germplasm, send a follow-up collecting mission.	GRU
	Misidentification of germplasm	Misleading information	Include taxonomists during collecting.			Use molecular methods to verify identity. Invite taxonomists and other experts to verify identity of ambiguous materials.	GRU
	Lack of simple collection protocol and documentation forms	Failure to capture diversity in field			Develop simple collecting procedures and forms.		GRU
	Agricultural intensification, replacement of traditional varieties with modern ones, urbanization, land use change, and climatic events	Loss of germplasm in habitat			Prioritize affected areas if containing germplasm that can fill gaps in collection.		GRU
	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.	Arrange for unrestricted use with new leaders of donor countries. Acquire material through friendly 3rd party countries. Offer technical incentives.	GRU
	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.	Keep acquired material under restricted use and access, and seek de-restriction with donor country.	Center top mgt; new employees orientation;GRU
	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.	Help build capacity of national bodies in germplasm collecting.	Center partnership and collaboration office, GRU
Donation	Received foreign materials carry pests and diseases	Introduction of pest and diseases to host country		Gene bank is located in a non banana growing country.	Strictly observe quarantine regulations. Keep from main storage areas until fully checked and decontaminated. Grow and regenerate materials in screenhouse or away from large crop production areas of local farms. Newly introduced samples are subjected to full virus indexing at INIBAP's Virus indexing Centres following FAO-IPGRI TGSMG.	Confine affected areas, discontinue planting of crop and eliminate other hosts in adjacent areas.	GRU; Germplasm Health unit
	Limited germplasm testing capability	Restricts international germplasm exchange		Develop testing and handling capability for pests and diseases of international importance.			GRU; Germplasm Health unit
	Reluctance to share germplasm due to IP rights	Restricts international germplasm exchange		Conduct training on benefits and limitations of IP rights.			GRU
	Working collections not duplicated in major genebanks	Failure to capture elite germplasm			Proactively conserve breeding materials.		GRU
CONSERVATION							
Registration	Unverified passport and other data submitted	Incorrect or unreliable passport data, and poor quality of scientific reports			Verify passport information with donor.	Classify accessions as 'tentative' until standard characterization, etiology and DNA analysis establish their identity.	GRU
	Received materials have low viability	Loss of germplasm			Obtain large amount of samples and handle properly.	Seed increase immediately.	GRU
	Limited storage space for clonal materials				Priority materials for in-vitro clonal collection: a) cultivars and elite breeding lines b) clones from center of origin (tetrapoids and diploid forms) c) clones from secondary centers of diversity d) clones with unique characteristics and/or specific resistances e) highly diverse clones based on molecular markers Conduct regular review to remove non-essential materials		
Conservation in *in vitro* Banks							
Sample Processing	Untrained or inefficient personnel in sample processing	Reduction of good quality propagules and accidental mixtures	Conduct regular training and enforce close supervision of personnel on detection and removal of infected, infested and mechanically damaged samples.		Subculture samples of an accession in two steps (separated in time /different operator). Maintain spare cultures of the previous subculture cycle until new subcultures are established.		GRU
	Source of material is infected	Loss of viability of propagules		Provide an isolated growth room for in vitro explants taken directly from the field to allow time to detect insect infestations and disease infection and prevent their spread to other cultures.	Use material from virus-tested, virus-free plants. Indicate whether material is untested in the database records, so that virus elimination procedures can be initiated immediately. Conduct surface disinfestation with chlorine bleach (NaOCl 0.5 to 1% or commercial bleach 10-15%). Soak explants in a fungicide if fungal contaminants are likely. Additional treatments include short periods of sonication in NaOCl, double disinfection, oil sprays or dips, and insecticide treatment of mother plant before explants are taken. Wrap explants in plastic wrap during transport to help decrease spread of field organisms.	Obtain virus-free materials from other institutes as replacement accessions if virus testing or elimination are not available on-site.	GRU; Germplasm Health unit
	Poor quality and/or suboptimal size of propagule	Loss of meristems			Have additional materials available and change growth conditions to improve quality. Conduct experimentation to establish optimal meristem size for moderate growth and multiplication for each genus.		GRU

	Weak mother plants	Short lifespan of propagules in storage			Collect plant material for tissue culture from vigorous and healthy mother plants. Improve in vitro introduction process.		GRU
	Ineffective pest and disease screening procedures during sample processing	Reduction of good quality propagules			If an isolation area is not available, new explants from the field should be wrapped and observed for mites and thrips for several subcultures.		GRU; Germplasm Health unit
	No efficient tissue sterilisation procedures	Poor quality of propagules			Conduct research on tissue sterilisation for in vitro introduction.		
	Lack of proper disposal procedures of contaminated plant materials	Increase in invitro contamination with pests and diseases and dissemination to new areas.			Autoclave all contaminated materials before discarding or cleaning vessels. Dispose in isolated areas.		GRU; Germplasm Health unit
	Ineffective thermotherapy procedure	Failure of explants to multiply			Conduct experimentation to establish thermotherapy procedure for propagules for moderate growth and multiplication for each genus. Treat materials sequentially in two groups. If the first group is damaged, change the protocol for the second group.		GRU
	Inappropriate media and conditions for culture initiation	Failure of explants to multiply			Conduct experimentation to establish media composition and culture conditions for moderate growth and multiplication for each genus. Use a triage system and store only the best growing		GRU
Germplasm Testing	Untrained personnel in health testing of propagules	Pest and disease damage and spread in collection	Train staff to be observant of unusual growth or symptoms in the cultures.				GRU; Germplasm Health unit
	Improper screening methods and monitoring regime	Pest and disease damage and spread in collection		Conduct regular monitoring of the cultures, storage rooms and growth room. Use a pyrethrum-based spray in culture rooms. Regularly check all sterilisation equipment and laminar air flow quality	Have a monitoring system for all contamination sources. Conduct bacteriogical testing of samples on a regular basis at initiation, during subculture and before storage and apply decontamination treatments. Remove and autoclave contaminated cultures, unless they are the only representatives of the germplasm. Handle infected cultures and potentially contaminated cultures at the end of the day to minimize spread of contamination.		GRU; Germplasm Health unit
	Microbes and pests are not apparent at initial testing but appear later.	Pest and disease damage and spread in collection			Test at explant initiation and at one or two month intervals.		GRU; Germplasm Health unit
	Untrained personnel in transgene detection	Loss of genetic integrity of other accessions					GRU/Biotechnology unit
	Inadvertent presence of transgene	Loss of genetic integrity of other accessions					GRU/Biotechnology unit
	Lack or improper determination of transgene presence	Inaccurate or wrong information regarding transgene presence					GRU/Biotechnology unit
	Limited quantity of high quality propagules	Loss of accession			Monitor plants in slow-growth storage every 3-4 months to assess their viability, for occurrence of necrosis, chlorosis, hyperhidricity, blackening, callus formation and defoliation. When the number of viable cultures of an accession drops to 3-12 or a certain percentage, or if the quality has drastically decreased, subculture the accession into a new set of fresh tissue cultures. Optimize slow growth process, monitor accession growth rate and plan successive subcultures. Subculture intervals can be as often as every 60 days or as far between as 1.5 years. East African highland banana cultivars and parthenocarpic bananas can be stored for extended periods. Musa balbisiana accessions have short storage life. Establish pot plants in the greenhouse for accessions with poor in vitro growth.		GRU
	Ineffective sterilization techniques	Loss of accession			To decrease contamination spread, flame tools with 70% ethanol with additional 95% ethanol dip or prior soapy water dip if desired. Use hot bead sterilizers instead of alcohol lamps.		GRU
	Misapplication of antibiotics	Loss of accession			Apply short (10 days) treatments in effective antibiotics in the growth medium to control bacterial contamination. Apply fungicide or use high-osmotic media to control fungal contamination.		GRU
	Somaclonal variation	Loss of genetic integrity			Use appropriate medium to assure genetic stability of in vitro collections. Monitor the plants for somaclonal variation, and grow abnormal plants to maturity in field or greenhouse to observe morphological changes. Genotypes prone to somaclonal variation should be monitored more closely. Develop molecular tools for somaclonal variation detection. Maintain DNA/dry leaf samples as reference samples for molecular integrity check.		GRU
Conservation Procedure	Errors in media preparation	Loss of accession			Use specific protocols for each procedure and write down all steps to back track eventual errors if necessary.		GRU
	Ineffective pre-treatment	Short lifespan of propagules in storage			Apply two weeks of growth on the storage medium in the normal growth room temperatures or apply cold acclimatization before placing in cold-storage.		GRU
	Chemical imbalance during culture	Abnormal growth of material			Check cultures for buildup of phenols, metabolites and browning in the medium and transfer as needed. Ensure proper hormone concentrations during propagation. Avoid high concentrations of cytokinins, which may affect genetic stability.		GRU

	Suboptimal culture methods for a broad range of genotypes				Conduct additional research to determine techniques suitable for a range of genotypes.		GRU
	Short storage life of propagules	Loss of viability			Develop methods for extending the life of in vitro collections. Adjust osmotic pressure of in vitro samples to extend life rather than use hormones where there is a risk of genetic change.		GRU
	Delayed inventory	Loss of material			Schedule inventories based on the shortest period between which reculture is needed within the genus.		GRU
	Late subculturing	Loss of viability			Conduct regular monitoring to assess need for re-culturing as when the number of replicates has been reduced to 3-12.		GRU
	Backlog in regeneration	Loss of viability			Periodically check viability and general performance of stored samples within recommended intervals. Back up accession with pot plants in the greenhouse if in vitro growth is experienced.		GRU
Storage Facility	Unsterile transfer facilities	Loss of accession		Design transfer facilities with minimal foot traffic and outside airflow.	Regularly check culture hoods for leaks with testing equipment (smoke) or with open bacteriological plates. Check for leaks whenever laminar flow hoods are moved.		GRU; Germplasm Health unit
	Unsuitable tissue culture containers for in vitro samples	Loss of accession			Carefully seal individual tissue culture containers of invitro samples with film against air-born contamination, pest attack and dessication. Culture replicates in separate TC containers to minimize container-specific risks.		GRU
	Poor laboratory maintenance	Contamination and loss of materials	Field and greenhouse personnel should change their shoes and clothing before entering the lab and growth rooms.	Routinely mop floors with disinfectant. Control dust and insects, especially mites. Regularly change or clean filters in the laminar flow hoods and building's ventilation system.	Autoclave contaminated cultures before they are washed or remove them from the lab to a separate washing area. New explants should be held in a separate room or the lids wrapped with tape or plastic wrap until the possibility of insects is ruled out. Wipe cultures introduced from other laboratories with 70% alcohol or bleach and isolated from the main culture room until cleared of insect infestations.		GRU
Safety Duplication	Safety duplication site is vulnerable to natural calamities	Inaccessible or loss of safety duplication			Store duplicates in at least two places for safety, either on-site in separate storage rooms or as black-box or active collection off-site. Establish a duplicate as base collection in liquid nitrogen (cryo).		GRU
Regeneration	Regeneration failure	Loss of germplasm			Adhere strictly to standard in vitro regeneration procedure. Unload loaded meristems, transfer to MS supplemented with 2.22 uIM BA, and finally to P6 medium.		GRU
Conservation in Cryo bank - Long Term Storage (LTS)							
Sample Processing	Incorrectly identified material is stored	Wrong germplasm stored and distributed			Use only verified materials		GRU
	Isolation of material is not done correctly, meristems are damaged and regrowth as callus	Increased chance of variation	Training of lab personnel		Use 0.8-1 mm long meristems with apical dome just partly covered by the bases of the first outer leaf primordia. Immediately place dissected meristems on MS medium supplemented with 0.1 M sucrose to prevent dessication.		GRU
	Chemical cryoprotectants injure plant cells during pre-treatment	Reduced viability during storage			Incubate banana meristems in loading solution before dehydration by vitrification.		GRU
	Plants are sensitive to preculture method	Loss of viability			Produce 'cauliflower-like' meristem clumps and preculture with sucrose or with vitrification.		GRU
	Technique does not work for all plants in the collection	Gaps in collection			Plan to have several techniques available for use		GRU
Germplasm Testing	Thawing/rewarming is done improperly	Underestimate of post-thaw regeneration rate	Training for staff		Quickly transfer cryotubes to liquid nitrogen-containing Dewar flask, and then to a 40C holding water bath. Partly drain out excess PVS2 solution on sterile filter paper and unload on MS with 1.2 M sucrose.		GRU
	Water bath may be contaminated	Damage to samples			Use sterile water in containers within the waterbath.		GRU
	New material in cryo-collection is not viable	Loss of samples			Conduct viability testing during initial processing and have a written protocol for all aspects of regrowth (medium, temperature, light)		GRU
Conservation Procedure	Dewars may fail.	Damage to samples			Use alarm systems and duplicate materials in a separate dewar.		GRU
	Unreliable supply of liquid nitrogen (LN)	Damage to samples			Ensure a reliable source of LN from specialized companies, local hospitals, industry or artificial insemination centres. Alternatively, a small LN manufacturing plant may be purchased. Use long-hold dewars and plan refills to ensure regular supply.		GRU/Purchasing
	Rapid loss of LN in dewar	Damage to samples			Provide a wide-mouth dewar for holding samples during processing and a narrow-mouth, long-neck dewar fo long-term storage. Use a sensor for low Liq N, with automatic text/page to 2-3 key staff when limits are reached. Conduct regular checks and fill dewars regularly. Replicate samples between two dewars.		GRU
	Improper placement on cryocane and to multiple rewarming and cooling cycles during sample retrievals	Loss of biological stability			Follow instructions closely on use of cryocane and dewar. Group samples based on demand level. Make more replicates of samples under heavy demand. Store long-term samples separately from often used samples		GRU
	Compromised integrity of cryovials	Contamination and loss of biological stability			Use cryovials with additional level of security such as cap-threads, a silicone gasket, plastic cryosleeves, and polyethylene membrane sealants.		GRU
	Insuffiicent number of stored propagules	Loss of germplasm			Determine the number of replicates for storage based on the survival rates achieved, crop type, speed of propagation and material available for storage.		GRU

Conservation on field banks							
Sample Processing	Low initial quality of explants.	Short lifespan of germplasm in storage			Collect plant material for field culture from vigorous and healthy mother plants.		GRU
	Improper conditioning and propagation of vegetative material	Short lifespan of germplasm in storage			Conduct immediate propagation, washing or disinfection, depending on the material.		GRU
	Failure in propagation and storage of propagules	Loss of germplasm			Group accessions based on general propagation procedures. Carry out research for genotypes that do not respond well to the general methods. Contact other facilities to obtain additional information on propagation of specific genotypes.		GRU
Germplasm Testing							
Health Diagnosis	Failure to detect and remove samples with pests and diseases and improper disposal of contaminated materials	Increased pathogen or pest population in the facility, thereby jeopardizing the health of other accessions in the collection as well as introducing new pest or diseases in new regions/countries.	Conduct regular training and enforce close supervision of personnel on proper disposal of contaminated materials.	If applicable, grow incoming and regeneration materials in screenhouse or in isolation away from large areas of local farms. Duplicate collection in two other sites, or keep an in vitro or a cryo set.	Subject regenerated material to usual phytosanitary testing. When new cuttings are established, incinerate the original plant and sterilize and discard the substrate. Monitor field regularly and immediately rogue diseased plants. Accessions with special vulnerability to particular diseases or pests may require special treatment such as being placed in screen or greenhouses or being treated for those diseases on a specific schedule.		GRU; Germplasm Health unit
	Ineffective screenhouse to control insects			Construct and manage screenhouses to prevent disease-carrying insects from entering. Workers and visitors should not enter the screenhouses after visiting field plots. The entryway into the screenhouses should have a set of two doors that should not be opened at the same time to reduce the entry of insects. Check screens and structures periodically to assure they remain insect proof.			GRU/ Physical Plant unit
	Backlogs in pest and disease monitoring	Loss of field bank samples	Hire and train adequate personnel to regularly monitor pest and diseases.				GRU
	False positive and false negative results during plant health testing.	Loss of materials due to false positive results. Dissemination of diseased materials due to false negative results.			Repeat tests in case of doubt and have replicates to confirm and have more reliable results.		GRU; Germplasm Health unit
Storage Monitoring	Limited numbers of viable plants	Loss of germplasm			Keep 3 to 20 vegetative propagules per accession.		GRU
	Mechanical mixtures or invasive plants	Loss of genetic integrity			Monitor the plants for offtypes and remove immediately.		GRU
	Late rejuvenation or multiplication (plants lost their physiologic vigour or accumulated pests and diseases)	Loss of materials			Monitor the genebank regularly and plan regeneration in advance.		GRU
Conservation Procedure	Inadequate selection, pre-conservation or pre-treatment of propagules	Poor plant establishment	Use trained personal and follow clear methodologies		Monitor all steps of sample preparation and take measures to avoid unecessary risks (plan the work to avoid interruptions and delays during weekends or hollidays). Prepare all materials in advance (chemicals, tools)		GRU
	Failure in propagation and storage of propagules	Loss of germplasm			Group accessions based on general propagation procedures and vegetative period. Carry out research for genotypes that do not respond well to the general methods. Contact other facilities to obtain additional information on propagation of specific genotypes.		GRU
	Inadequate number of replicates per accession.	Loss of germplasm			Increase number of replicates per accession to represent the genetic variability of the accessions.		GRU
Field Bank Specifications							
Field Monitoring	Unsuitable conditions in conservation site	Poor or suboptimal growth		Select a conservation site that is safe, favours plant development of the target germplasm, and isolated to prevent pest attacks and diseases but with easy access for management. Ensure that the climate and ecology of the site are conducive to			GRU
	High pest and disease pressure in field site	Loss of germplasm		Use screenhouse (SH) culture to provide the best protection against worst diseases, insects and pests.			GRU; Germplasm Health unit; Physical Plant unit
Field Planting	Pollen exchange with plants within and outside collection.	Loss of genetic integrity		Isolate site from potential pollinators if intended for outcrossing species.	Arrange the plants at good spacing distance to prevent plants from exchanging pollen. Bag reproductive structures and manage insect pollinators, or use individual mesh houses for each accession. Research needed on outcrossing rates of certain taxa can guide field layouting.		GRU
	Misidentification	Loss of germplasm			Develop field maps and use them during planting, evaluation and harvest. Record and identify with name and accession number all plants in the field on maps. Use weather resistant, and if possible, computer-generated labels.		GRU
	Mixtures of clones	Loss of genetic integrity			Provide adequate spacing between accessions taking into consideration the adult size growth habit of the plants. Plants that readily spread by rhizomes or runners may require wider spacing between plots to prevent clones from mixing. Accessions with different morphologies may be planted in adjacent plots when creeping or spreading is a problem. Particularly, invasive clones may require planting in cans, pots or boxes to reduce mixing or competition with less vigorous accessions. Prune plants if necessary.		GRU
	Contamination with volunteer plants.	Loss of genetic integrity			Use adequate crop rotation system. Let volunteers grow after field preparation and remove them before planting new materials.		GRU

Field Maintenance& Management	Mixtures of fruits and germplasms	Loss of genetic integrity			Conduct thinning and pruning to prevent overlapping between plants and mixtures of fruits and germplasms.		GRU
	Poor adaptation	Loss of germplasm			Monitor collection frequently and transfer struggling accessions to possible alternative sites such as greenhouse or in vitro culture. Research is needed to study and understand the specific environmental requirements of different accessions in order to better manage them in field genebank.		GRU
	Disparate location of physiologically similar accessions	Inefficient management			Plant accessions in groups according to vigour, height, branching habit or lodging tendencies. Crops that must be harvested on a regular basis should be planted in groups by harvest dates or time to maturity.		GRU
	Poor management of weeds and low soil fertility	Loss of germplasm			Control weeds to limit competition and reduce weed-borne pathogens and insects. Monitor soil fertility and adjust as needed.		GRU
Post-harvest Handling	Persistence of disease organisms and insects after harvest	Deterioration of propagules and spread of pests and diseases during storage			Treat tubers with fungicide and insecticide before storage. Closely monitor for bacterial and fungal infections, and immediately remove rotten tubers to prevent them from infecting other healthy tubers.		GRU; Germplasm Health unit
	Mishandling	Deterioration of propagules during storage			Take extreme care during harvest and transportation to avoid physical damage to tubers.		GRU
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.		GRU
	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.	Re-characterize accessions for problematic traits using current international standard descriptors.	GRU
	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.		GRU
	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	Determine a set of core collection and begin eliminating redundant duplicates of the core materials.	GRU
DISTRIBUTION							
Policies	Lack of knowledge or negligence on germplasm 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 the germplasm.	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.	Immediately send correct documents and information to recipient of germplasm, including acknowledgment receipt and agreement forms to be completed and returned.	GRU; Plant Breeding; Training
	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.	Send a notice to patent and PVP offices about status of germplasm materials in question. File legal suit against violators and prohibit their access to IT germplasm.	GRU; Center Mgt; FAO
	Plant health restrictions of importing country	Low level of exchange and utilization of germplasm.			Conduct research on plant sanitation to facilitate germplasm exchange.		
	Non compliance with phytosanitary regulations	Germplasm distributed from genebank with diseases or pest contamination.			Test materials for bacterial and fungal diseases in compliance and germplasm health checks according to the phytosanitary standards of the importing country. Accompany outgoing material with an import permit from the requesting country and a phytosanitary certificate. Only accessions that are tested "virus-negative" at the INIBAP virus indexing center are made available for distribution. Samples are distributed as aseptic tissue cultures. Outgoing material must be accompanied by a Belgian Plant Passport for destination within the EU. A Belgian Phytosanitary Certificate accompanies each shipment outside EU.	Immediately send disease and pest management procedures to recipients of germplasm.	GRU; germplasm Health
User Service	Germplasm distributed are weak	Dissatisfied recipients of germplasm			Select 7 proliferating cultures per accession in MTS and subculture under normal growth conditions for about 5 weeks. Trim and transfer to fresh medium under normal growth conditions for two weeks. Select five best cultures for dispatch to requestors with access to invitro laboratory and micropropagation. For sending rooted plantlets, subculture 3-6 times over ten weeks on regeneration medium, transfer 8 cultures to culture vessel for three weeks, and select five best cultures for dispatch.		GRU
Germplasm Preparation and Dispatch	Misclassification and wrong characterization and germplasm stocks data	Delayed identification and preparation of requested germplasm	Conduct regular training on germplasm characterization.		Check characterization data specially the easily identifiable characters. Include evaluation data that relate to needs of the possible different users. Request all germplasm recipients within and outside Center to share their generated data related to the provided germplasm.	Acknowledge receipt of germplasm request. If there is reasonable doubt on identity and availability of requested germplasm, notify requester of possible delay of delivery pending confirmation of identity and availability.	GRU, Library, Communications Office
	Inefficient and slow processing of requests for samples.	Dissatisfied recipients of germplasm	Dedicate personnel to serving germplasm requests.		Keep files of relevant country and international quarantine documents .		GRU; germplasm Health
	Errors in preparing or labeling samples	Wrong germplasm distributed by the genebank			Adopt barcoding and closely adhere to germplasm distribution protocol.	Immediately send correct germplasm and instructions on disposing received wrong germplasm. Recipient should be required to send written confirmation of compliance with the disposal procedures.	GRU
	Insufficient germplasm stock for distribution	Delay in serving germplasm request			Incorporate alerts in the computerized germplasm stock control system to call attention to need for mutlipication and regeneration. Keep plenty of popular genetic stocks in the active set as well as their DNA samples if available.	Conduct germplasm mutliplication of the accessions concerned and notify requestor of expected date of germplasm availability. Make an agreement with requestor on funding and schedule of germplasm increase, if Center cannot immediately meet	GRU

	Bulky tissue-cultured explants	Expensive shipping cost and vulnerability of material to disintegration			Use space-saving growth bags with 2 layers of zip-up.		
	Lack or incomplete documentation about germplasm and feedback form on condition upon arrival	Misidentification, mishandling and/or loss of germplasm, and unknown status of sent germplasm			Accompany shipment by a letter, packing list and a questionaire on the condition of the material upon arrival to be completed by the receiver and returned to the ITC. Enclose protocol on handling propagules or rooted plantlets after unpacking.		
	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. Use the safest shipment services with reliable tracking system.	If route and time taken by material are unreasonably extended, resend new germplasms using an alternative courier.	GRU
INFORMATION MANAGEMENT AND DISSEMINATION							
	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.		GRU, IT unit
	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 germplasm exchange policy databases.	Regularly monitor data handling and encode stray data.	GRU, IT unit
	Improper recording of moisture content, germplasm inventory, viability, storage location, and characterization data.	Inaccurate or wrong information			Independently verify encoded data. Automate computing, updating and reporting germplasm inventory, viability, storage location, and characterization data in database. Provide decision-making tools in the database for various genebanking operations.	Re-encode inventory and viability data from data sheets if reliable, otherwise repeat inventory and viability tests.	GRU
	Lack of adequate information about important characteristics of each accession.	Low interest and utilization of germplasm			Collect data on important traits. Include desirable information from various sources.		GRU
	Mislabelling of new bags and other containers for the germplasm accession and samples are placed in the wrong container.	Loss or misplacement of materials			Set up a standard protocol for labeling and placement of samples from registration to regeneration to harvesting. One label should follow an explant through the entire process. Use a mixture of letters and numbers to decrease the possibility of transposing numbers. Use a barcoding system to keep track of all accessions. Use preprinted labels to reduce human error. Use scanners and pocket PCs in data gathering. Use labeling that does not require continual rewriting of the label. Maintain lyophilized leaf samples of each accession as a reference for identification.		GRU
	Lack of secure back-up	Loss of genebank data		Transfer new data on CD or tape in two central databases kept in separate buildings in the institute. They can be stored also in secure, passport-regulated cyberspace.	Produce hard photocopy and electronic copy of original data sheets. Use automatic back-up on transaction computer after each session. Make daily incremental back-ups and weakly full back-ups.	Retrieve data from back-up electronic copies and /or paper records if available. Otherwise, conduct germplasm stock inventory and retake viability tests of materials, prioritizing the weakest germplasm types based on experience and literature. Hire necessary personnel to complete work as quickly as possible.	GRU, IT unit
	Important data and information remain in unuseful form.	Low level of utilization of germplasm and information.			Disseminate relevant information about germplasm and genebank operations by publishing in germplasm catalogs, newsletters, journals, bulletins, and operation manuals in print and cyber media.	Provide on-demand technical assistance for special data and information search about germplasm.	GRU, Library, Communications Office
	Outdated or inaccessible procedures manual	Loss of improvements in procedures			Write out in detail all procedures and recipes in a procedures manual as a reference guide for workers. Update the manual yearly or any time major procedure changes are instituted.		GRU
	Inconsistent protocols	Much variation in quality of process outputs			Develop standard protocols and recipes. Design media sheets as worksheets to minimize errors. When new protocols and recipes are developed, file the old ones for reference.		GRU
	Lack or complicated tracking and inventory system	Loss or misplaced samples and failure to regenerate and serve germplasm request on time			Design a computer inventory system that will allow researchers to follow each accession from acquisition through culture and storage. The system should include and link acqusition information, field data, image data and in vitro records for each accession. Include storage date, location in dewar, number of vials, number of meristems per vial, technique used, thawing technique required, recovery medium and other important procedures.		GRU
	Insufficient data on accession identity and culture conditions	Underestimate of germplasm viability or failure to propagate by recipient			Include each accession's explanting date, source, initiation medium, multiplication medium, rooting medium, growth information, experimental data, length of subculture, etc. Identify plants by the same numbering or labelling system as the field genebank to allow the plants to be traced back to the mother plant when necessary.		GRU
	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 every year.	Regulate software installation and downloading. Restrict use of computer to authorized personnel.	Provide information request menu on the webpage and serve requests by digging print and/or electronic records.	GRU, IT unit
	Malfunctioning equipment, hardware and software problems	Failure to update data by genebank staff. Delays in recording of accessions and declaring them to FAO & SINGER		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.		GRU
INFRASTRUCTURE/PHYSICAL FACILITY							

	Storage conditions at genebank not suitable (temperature, humidity, light conditions, exposure to contaminating organisms, pests)	Reduction or loss of viability		Treat culture rooms with pesticides on a regular time basis. Regularly check and maintain cooling units. Maintain storage room conditions and monitor conditions daily via remote sensing devices. Install a High Efficiency Particle-removal Air system (HEPA) and alarm systems for open doors, temperature/ humidity changes in the culture areas. Provide a dehumidifier. For MTS, store cultures at 15±1°C and 2000 lux.	Conduct regular monitoring and cleanup to prevent fungus problems especially in tropical climates. Monitor MTS materials every 3-4 months for occurrence of necrosis, chlorosis, hyperhidricity, blackening, contamination, callus formation and defoliation. Develop in vitro diagnostic tools.	Multiply, carefully process and send accessions to better genebanks for safety back-up.	GRU, Physical Plant
	Poor organization of storage trays, shelves and compartments	Loss or misplacement of germplasm	Restrict storage facility access to authorized genebank personnel.	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.		GRU
	Deterioration of facilities and equipment	Reduction or loss of viability		Pursue continual upgrading and expansion of field and laboratory equipment, etc.			GRU
	Cold room malfunction	Reduction or loss of 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.			GRU, Physical Plant
	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.			GRU, Physical Plant
	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.		GRU, Physical Plant, Security
	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 automatic fire and gas alarm systems and provide fire isolation doors and fire extinguishers. Provide 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.		GRU
Safety Duplication	Safety duplication site is vulnerable to natural calamities	Inaccessible or loss of safety duplication		Establish duplicate back-up in a geologically secure site with low radiation (radioactivity) and stable (low probability of earthquakes). The facility must be situated at an altitude that guarantees proper drainage during seasonal rains and eliminates the risk of flooding in the event of rising sea levels due to global warming.			GRU
	Changing policies, financial and technical capabilities of governments hosting safety duplication	Inaccessible or loss of safety duplication		Establish safety backup arrangements in two different, economically stable countries, preferably in different continents, for black-box storage. Prepare a pull-out scheme in the event of instability in host country. Duplicate collection in two other sites, or keep an in vitro or a cryo set.			Center top mgt; SGRP; GRU
PERSONNEL AND SUPPORT SERVICES							
	Inadequate complement of technical staff	Inefficient operations	Hire at least one highly qualified technician each to manage germplasm viability test, germplasm drying and moisture test, germplasm health test, characterization and regeneration, data management, and germplasm 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 germplasm cleaning, germplasm processing and germplasm packaging, and field workers for germplasming, field-layout, screenhouse and field maintenance and harvesting.				GRU; HR unit
	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.				
	Routine tasks and uncompetitive remuneration	Fast staff turnover	Rotate work assignments as much as possible or assigning special projects to laboratory assistants. Train each assistant to make medium, wash dishes, transfer cultures, check cultures for contaminants, do basic record keeping, and other required laboratory tasks. Educate workers on the mission of the facility to provide a morale boost and establish a research-oriented approach to work.				GRU
	Exposure to occupational hazards	Reduced manpower capability		Provide potective clothing, gloves and safety devices such as showers, eyewash and fire extinguishers.	Protect staff members from pesticide exposure, for example, by spraying during weekends.		GRU, Pest Control unit

	Suffocation/asphyxiation and frostbite and cold injury from LN exposure. Mechanical injury incurred on explosion of a pressurized vessel containing LN.		LN safety considerations should be included in the training of all new staff.	Well-ventilated room; handling and storage dewars must be vented; skin and eyes must be protected with cold-resistant gloves, aprons, safety glasses and closed-top shoes. Only LN-resistant vessels and instruments guaranteed by the manufacturer should be exposed to its vapor and liquid phases. Install oxygen level sensors and self-contained breathing apparatus.Install door magnetic locks that automatically unlock during emergencies.	Enforce pal system when entering cryo tank area. Constantly monitor cryo tank area on closed-circuit tv.		GRU
	Inefficient human resources services	Delayed hiring of required manpower			Review and streamline hiring/recruitment protocol.		HR
	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)	Tap equipment and supplies of partner organizations, for a fee if required, pending delivery of ordered equipment and supplies.	GRU
	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.	Charge shipping fees to recipients of germplasm especially the private sector and well-funded public organizations.	GRU; Center mgt