Table 2c. Potential risks and management options for clonal banks.

Activity	Risk Sources/Indicators	Risk/Consequence	Action Plan		
			People	Facility	
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 collectior conduct gap-filling
	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 c
	Agricultural intensification, replacement of traditional varieties with modern ones, urbanization, land use change, and climatic events	Loss of germplasm in habitat			Prioritize affected that can fill gaps i
	Strict country and international laws on access and use of germplasm	Poor access and use of germplasm in unexplored areas			Secure a Germpla between donor co accessions under
	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 pr permits, under rel Collect in partners
	Ambiguous position of countries regarding international treaties	Poor access and use of germplasm in unexplored areas			Foster goodwill th breeding and Trea and incentivize do
Donation	Received foreign materials carry pests and diseases	Introduction of pest and diseases to host country			Strictly observe qu main storage area decontaminated. screenhouse or a
	Limited germplasm 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 conse
CONSERVATION					
Registration	Unverified passport and other data submitted	Incorrect or unreliable passport data, and poor quality of scientific reports			Verify passport in
	Received materials have low viability	Loss of germplasm			Obtain large amou properly.

	Limited storage space for clonal materials				Priority materials a) cultivars and el b) clones from ce diploid forms) c) clones from se d) clones with uni resistances e) highly diverse markers Conduct regular r 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 sampl (separated in time spare cultures of new subcultures a
	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 Indicate whether database records procedures can b surface disinfesta 0.5 to 1% or comm explants in a fung likely. Additional t sonication in NaO or dips, and insec before explants a wrap during trans
	Poor quality and/or suboptimal size of propagule	Loss of meristems			Have additional m growth conditions experimentation t for moderate grow
	Weak mother plants	Short lifespan of propagules in storage			Collect plant mate vigorous and heal vitro introduction
	Ineffective pest and disease screening procedures during sample processing	Reduction of good quality propagules			If an isolation area from the field sho mites and thrips f
	No efficient tissue sterilisation procedures	Poor quality of propagules			Conduct research 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 cont discarding or clea areas
	Ineffective thermotherapy procedure	Failure of explants to multiply			Conduct experime thermotherapy pr moderate growth Treat materials se first group is dam
	Inappropriate media and conditions for culture initiation	Failure of explants to multiply			Conduct experime composition and growth and multip triage system and
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.		

	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 sources. Conduc on a regular basis and before storag treatments. Rem cultures, unless th of the germplasm potentially contam day to minimize s	
	Microbes and pests are not apparent at initial testing but appear later.	Pest and disease damage and spread in collection			Test at explant ini intervals.	
	Untrained personnel in transgene detection	Loss of genetic integrity of other accessions				
	Inadvertent presence of transgene	Loss of genetic integrity of other accessions				
	Lack or improper determination of transgene presence	Inaccurate or wrong information regarding transgene presence				
	Limited quantity of high quality propagules	Loss of accession			Monitor plants in s months to assess necrosis, chlorosi callus formation a of viable cultures a certain percenta decreased, subcu set of fresh tissue process, monitor a successive subcu	
	Ineffective sterilization techniques	Loss of accession			To decrease cont with 70% ethanol or prior soapy wat sterilizers instead	
	Misapplication of antibiotics	Loss of accession			Apply short (10 da antibiotics in the g contamination. Ap media to control fu	
	Somaclonal variation	Loss of genetic integrity			Use appropriate m of in vitro collectio somaclonal variat maturity in field or morphological cha somaclonal variat closely. Develop variation detection as reference sam	
Conservation Procedure	Errors in media preparation	Loss of accession			Use specific proto down all steps to necessary.	
	Ineffective pre-treatment	Short lifespan of propagules in storage			Apply two weeks in the normal grow cold acclimatizatio	
	Chemical imbalance during culture	Abnormal growth of material			Check cultures fo and browning in th needed. Ensure p during propagatio cytokinins, which	
	Suboptimal culture methods for a broad range of genotypes				Conduct additiona techniques suitab	

	Short storage life of propagules	Loss of viability			Develop methods collections. Adjus samples to extend where there is a r
	Delayed inventory	Loss of material			Schedule inventor between which re genus.
	Late subculturing	Loss of viability			Conduct regular r culturing as when been reduced to 3
	Backlog in regeneration	Loss of viability			Periodically check performance of st recommended int pot plants in the g experienced.
Storage Facility	Unsterile transfer facilities	Loss of accession		Design transfer facilities with minimal foot traffic and outside airflow.	Regularly check c equipment (smok plates. Check for hoods are moved
	Unsuitable tissue culture containers for in vitro samples	Loss of accession			Carefully seal indi invitro samples wi contamination, pe replicates in sepa container-specific
	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 contam washed or remov washing area. Ne separate room or plastic wrap until out. Wipe cultures laboratories with isolated from the insect infestations
Safety Duplication	Safety duplication site is vulnerable to natural calamities	Inaccessible or loss of safety duplication			Store duplicates i either on-site in s box or active colle duplicate as base (cryo).
Regeneration	Regeneration failure	Loss of germplasm			Adhere strictly to procedure.
Conservation in Cryo bank - Long Term Storage (LTS)					
Sample Processing	Incorrectly identified material is stored	Wrong germplasm stored and distributed			Use only verified
	Isolation of material is not done correctly, meristems are damaged and regrowth as callus	Increased chance of variation	Training of lab personnel		
	Chemical cryoprotectants injure plant cells during pre-treatment	Reduced viability during storage			Optimize procedu
	Plants are sensitive to preculture method	Loss of viability			Choose another p
	Technique does not work for all plants in the collection	Gaps in collection			Plan to have seve
Germplasm Testing	Thawing/rewarming is done improperly	Underestimate of post-thaw regeneration rate	Training for staff		Have standard pr
	Water bath may be contaminated	Damage to samples			Use sterile water waterbath.
	New material in cryo-collection is not viable	Loss of samples			Conduct viability t and have a writte regrowth (medium
Conservation Procedure	Dewars may fail.	Damage to samples			Use alarm system separate dewar.

	Unreliable supply of liquid nitrogen (LN)	Damage to samples			Ensure a reliable companies, local insemination cent manufacturing pla hold dewars and p supply.
	Rapid loss of LN in dewar	Damage to samples			Provide a wide-m during processing dewar fo long-terr Liq N, with autom when limits are re and fill dewars re
	Improper placement on cryocane and to multiple rewarming and cooling cycles during sample retrievals	Loss of biological stability			Follow instruction dewar. Group sam Make more replic demand. Store lo often used sampl
	Compromised integrity of cryovials	Contamination and loss of biological stability			Use cryovials with as cap-threads, a cryosleeves, and
	Insuffiicent number of stored propagules	Loss of germplasm			Determine the nu based on the surv speed of propaga storage.
Conservation on field banks					
Sample Processing	Low initial quality of explants.	Short lifespan of germplasm in storage			Collect plant mate and healthy moth
	Improper conditioning and propagation of vegetative material	Short lifespan of germplasm in storage			Conduct immedia disinfection, depe
	Failure in propagation and storage of propagules	Loss of germplasm			Group accessions procedures. Carr do not respond w Contact other faci information on pr
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 regenerat phytosanitary test established, incin sterilize and disca regularly and imm Accessions with s diseases or pests such as being pla being treated for t schedule.
	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.	
	Backlogs in pest and disease monitoring	Loss of field bank samples	Hire and train adequate personnel to regularly monitor pest and diseases.		
	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 ca to confirm and ha

Storage Monitoring	Limited numbers of viable plants	Loss of germplasm			Keep 3 to 20 vege	
	Mechanical mixtures or invasive plants	Loss of genetic integrity			Monitor the plants immediately.	
	Late rejuvenation or multiplication (plants lost their physiologic vigour or accumulated pests and diseases)	Loss of materials			Monitor the genet regeneration in ac	
Conservation Procedure	Inadequate selection, pre-conservation or pre-treatment of propagules	Poor plant establishment	Use trained personal and follow clear methodologies		Monitor all steps c measures to avoi to avoid interrupti or hollidays). Prep (chemicals, tools)	
	Failure in propagation and storage of propagules	Loss of germplasm			Group accessions procedures and v research for geno the general metho obtain additional i specific genotypes	
	Inadequate number of replicates per accession.	Loss of germplasm			Increase number represent the gen	
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 maintenance.		
	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.		
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 plant prevent plants fro reproductive struc pollinators, or use accession. Rese rates of certain ta	
	Misidentification	Loss of germplasm			Develop field map evaluation and ha name and access on maps. Use we computer-generat	
	Mixtures of clones	Loss of genetic integrity			Provide adequate taking into consid of the plants. Pla rhizomes or runne between plots to p Accessions with d planted in adjacer spreading is a pro clones may requir to reduce mixing c accessions. Prune	
	Contamination with volunteer plants.	Loss of genetic integrity			Use adequate cro grow after field pr before planting ne	
Field Maintenance& Management	Mixtures of fruits and germplasms	Loss of genetic integrity			Conduct thinning overlapping betwe and germplasms.	

	Poor adaptation	Loss of germplasm			Monitor collection accessions to pos greenhouse or in to study and unde requirements of d better manage the
	Disparate location of physiologically similar accessions	Inefficient management			Plant accessions height, branching Crops that must b should be planted time to maturity.
	Poor management of weeds and low soil fertility	Loss of germplasm			Control weeds to weed-borne patho fertility and adjust
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 storage. Closely m infections, and im prevent them from
	Mishandling	Deterioration of propagules during storage			Take extreme car transportation to a
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 ver computing, updati characterization d
	Descriptors that have no clear-cut correspondence to current international standard descriptors	No or limited usefulness of characterization data			Use updated desc all measurements
	Limited text-based description	Incomplete and inaccurate morphological description			Include images (6 accompanied with colors.
	Lack of diversity assessment of collection	Unknown level of breadth, duplication and gaps in collection, and conservation of unnecessary duplicates			Conduct molecula
			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 clear distribution ensuri documents and ap are obtained befo
	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 accessi CGIAR MTA for " Center-created "n developed in colla CGIAR Center, w Center to take leg the MTA, upon re conditions.
	Plant health restrictions of importing country	Low level of exchange and utilization of germplasm.			Conduct research germplasm excha
	Non compliance with phytosanitary regulations	Germplasm distributed from genebank with diseases or pest contamination.			Test materials for compliance and g according to the p importing country. with an import per and a phytosanita
User Service	Germplasm distributed are weak	Dissatisfied recipients of germplasm			

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 characteriz identifiable charac relate to needs of Request all germp outside Center to related to the prov
	Inefficient and slow processing of requests for samples.	Dissatisfied recipients of germplasm	Dedicate personnel to serving germplasm requests.		Keep files of relev quarantine docum
	Errors in preparing or labeling samples	Wrong germplasm distributed by the genebank			Adopt barcoding a distribution protoc
	Insufficient germplasm stock for distribution	Delay in serving germplasm request			Incorporate alerts stock control syst mutlipication and popular genetic st their DNA sample
	Bulky tissue-cultured explants	Expensive shipping cost and vulnerability of material to disintegration			Use space-saving up.
	Unfavorable conditions during transport	Delay in delivery , reduction of viability or loss of materials			Use packing mate unfavorable condi and under dry-ice shipment services
INFORMATION MANAGEMENT AND DISSEMINATION					
	Inefficient recording and database management	Backlog and inaccurate characterization data			Use GRU Databa to SINGER every in books.
	Mishandling of information and disorganized data sets (e.g. information system, field/ lab observation)	Loss or inaccessibility of information			Use GRU Databa data sheets. Integ distribution record policy databases.
	Improper recording of moisture content, germplasm inventory, viability, storage location, and characterization data.	Inaccurate or wrong information			Independently ver computing, updati inventory, viability characterization d making tools in th genebanking oper
	Lack of adequate information about important characteristics of each accession.	Low interest and utilization of germplasm			Collect data on im information from
	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 placement of sam regeneration to ha an explant throug mixture of letters a possibility of trans barcoding system Use preprinted lab scanners and poo labeling that does the label. Maintain accession as a re
	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 pho original data shee transaction compu daily incremental ups.
	Important data and information remain in unuseful form.	Low level of utilization of germplasm and information.			Disseminate relev germplasm and g in germplasm cata bulletins, and ope media.

	Outdated or inaccessible procedures manual	Loss of improvements in procedures			Write out in detail procedures manu workers. Update t major procedure c	
	Inconsistent protocols	Much variation in quality of process outputs			Develop standard media sheets as v When new protoc file the old ones fo	
	Lack or complicated tracking and inventory system	Loss or misplaced samples and failure to regenerate and serve germplasm request on time			Design a compute researchers to fol acquisition throug system should inc information, field d records for each a location in dewar, meristems per via technique require important procedu	
	Insufficient data on accession identity and culture conditions	Underestimate of germplasm viability or failure to propagate by recipient			Include each acce initiation medium, medium, growth in length of subcultu same numbering genebank to allow the mother plant w	
	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 Restrict use of co	
	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 home phones in c problems. Back u kept in Center, the and later in the int	
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.	Conduct regular m fungus problems Monitor MTS mat occurrence of nec blackening, conta defoliation. Devel	
	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 space units. Conc verification of loca on computerized	
	Deterioration of facilities and equipment	Reduction or loss of viability		Pursue continual upgrading and expansion of field and laboratory equipment, etc.		
	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.		

	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.	
	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 personnel with as access. Conduc who will use facili on the safety and 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 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 genebank during leaks in the cold a check fire safety
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.	
	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.	
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.		
	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.			
	Exposure to occupational hazards	Reduced manpower capability		Provide potective clothing, gloves and safety devices such as showers, eyewash and fire extinguishers.	Protect staff mem example, by spra	
	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 syste Constantly monit tv.	
	Inefficient human resources services	Delayed hiring of required manpower			Review and strea	
	Inefficient purchasing and repair services	Delayed delivery/repair of required supplies and equipment			Review purchasin process. Keep sp equipment in stoc available), as a ris batteries, lamps, f	
	High cost of genebank operations	Loss of donor and user support			Closely follow and The Global Crop I donors.	