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Revised genebank standards for management of plant genetic resources

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ABSTRACT

Genebanks are storehouses of genetic resources which have the primary responsibility of collecting, regenerating, conserving, characterizing, evaluating, documenting and distributing germplasm. With reference to plant genetic resources (PGR), today over 1,750 genebanks have been established worldwide, wherein 7.4 million accessions are maintained as *ex situ* collections in either seed banks, field genebanks, *in vitro* genebanks and/or cryogenebanks. To ensure that PGR are conserved in genebanks under recognized and appropriate conditions globally, the United Nations Food and Agriculture Organization (FAO) in collaboration with the International Board of Plant Genetic Resources (IBPGR) published the original *Genebank Standards* in 1994. Subsequently with advancements in science and technology, and changes in policy issues related to genetic resources, a need arose to revise the *Genebank Standards.* A consortium of global, regional and national stakeholders led by the FAO, Bioversity International, Global Crop Diversity Trust (GCDT), International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and International Plant Protection Convention (IPPC) prepared the revised version of the *Genebank Standards.* During the Fourteenth Regular Session of the Commission on Genetic Resources for Food and Agriculture (CGRFA) of the FAO the document on revised *Genebank Standards* was endorsed on 18 April 2013 and subsequently published as *Genebank Standards for Plant Genetic Resources for Food and Agriculture.* These revised genebank standards have a universal value and utility in guiding genebank management for seeds (orthodox and non-orthodox) and vegetatively propagated crops. It can be used by genebank curators as a source of guidance for developing standard operating procedures. We have compared the draft revised *Genebank Standards* (2013) with the original *Genebank Standards* (1994) to highlight the key features, along with some historical account on genebanks and development of standards.

Key words: CGRFA, *Ex situ* conservation, Genebank, Genebanks Standards, Plant genetic resources

Plant genetic resources (PGR) are raw materials that are the storehouse of valuable traits, which have been used for tailoring new and better crops since the beginning of agriculture. The importance of PGR has increased in contemporary times, to meet the challenges of the future such as adapting crops for changing climatic conditions and combating abiotic/biotic stresses. Due to anthropogenic activities and several other factors, valuable genetic diversity is under threat. In such a situation, the role of genebanks has become of paramount importance, providing a safe method of *ex situ* conservation of genetic resources. Genebanks have the primary responsibility of collecting, regenerating, conserving, characterizing, evaluating, documenting, distributing the germplasm. Additionally, they also provide security by maintaining 'safety duplicates' of unique and important genetic resources. To carry out all the activities efficiently and cost-effectively, uniform and high standards are required at international level. The Commission on Genetic Resources for Food and Agriculture (CGRFA) of the United Nations Food and Agriculture Organization (FAO) in its Fourteenth Session held in Rome, Italy, on 18 April, 2013, endorsed and adopted the revision of *Genebank Standards* (http://www.fao.org/docrep/meeting/027/mf804e.pdf), previously published in 1994 (FAO/IPGRI 1994). These standards are meant to ensure that plant genetic resources for food and agriculture (PGRFA) are conserved in genebanks under recognized and appropriately uniform conditions, based on current technological and scientific knowledge (Tyagi and Agrawal 2013). Simply defined, genebanks are places where either seeds are conserved at low temperature and moisture, or whole plants/plant propagules are conserved in field or culture vessels or in cryovials (Tyagi and Agrawal 2013). The new international standards are expected to help genebanks worldwide to conserve crop diversity holistically in a more efficient, safe and cost-effective manner.

In this paper, along with some historical account on genebanks and its standards, a comparison has been made between the Draft *Revised Genebank Standards* (2013) with the original *Genebank Standards* (1994) to highlight the key features.

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HISTORY OF PLANT GENEBANKS AND GLOBAL PGR COLLECTIONS

Genetic conservation of crops in genebanks is a relatively recent phenomenon (since the 1960s) in the time-frame of agricultural history (~12,000 years before present) (Plucknett *et al*. 1987). It was prompted by the need of scientists who required a constant and reliable supply of germplasm, and did not want to depend on plant exploration trips alone. The Russian Plant Explorer, Geneticist and Breeder, Nikolai Ivanovich Vavilov and many others discovered the importance of genetic diversity in breeding high yielding varieties and to overcome different yield reducing factors. Vavilov established the 'All-Union Institute of Plant Industry', Leningrad (St Petersburg) in the 1920s, which was the first genebank. However, in the beginning, seeds were kept at ambient temperature and had to be grown out every year. It was only in 1958 that the National Seed Storage Laboratory, Fort Collins, Colorado, was established by the US Department of Agriculture (USDA). It was the first national genebank that stored collection of all major crops from all over the world at low temperature (Plucknett *et al.* 1987).

The concept of institutionalized global collections and genebank conservation of plant genetic resources (PGR) was initiated and brought the issue into focus by the FAO in the 1960s. A 'Technical Meeting on Plant Exploration and Conservation' was co-hosted in 1967 by the FAO and the International Biological Program (IBP) to evaluate the danger of loss in crop genetic diversity and define a global strategy for conservation of PGR. Subsequently, an FAO 'Panel of Experts on Plant Exploration and Introduction' met four times in 1969, 1970, 1973 and 1974; which recommended, amongst other things, the establishment of a series of genebanks for long-term conservation of PGR (Dhillon and Agrawal 2004). Simultaneously, creation of International Agricultural Research Centres (IARC) to carry out research on important crops to combat hunger and food scarcity also occurred in the same period. The IARCs were supported by national governments and funding agencies such as Ford Foundation and Rockefeller. A Consultative Group on International Agricultural Research (CGIAR) was established in 1971 as a voluntary association of donors supporting the then existing four IARCs (IRRI, CIMMYT, CIAT and IITA), and for promotion of sustainable agriculture for food security in the developing countries. Currently, the CGIAR supports 16 IARCs. The CGIAR has played a key role in international PGR network through its *ex situ* collections in various IARC genebanks. The major activity of collecting and conservation of PGR was spearheaded by the International Board of Plant Genetic Resources (IBPGR), Rome, Italy, a CGIAR partner established in 1974. The IBPGR was rechristened in 1992 as the International Plant Genetic Resources Institute (IPGRI) and again renamed as Bioversity International in 2008. Besides the CGIAR many regional and national networks exist which link genebanks worldwide. The conservation of PGR has gained significantly in importance and is now accepted as an essential responsibility of national governments. This is demonstrated by the impressive number of nations which have ratified the Convention on Biological Diversity (CBD 1993) and endorsed the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA 2004), or both.

The first and second reports on the *State of the World's Plant Genetic Resources for Food and Agriculture* provide a comprehensive and authentic account of PGR status at the global level (FAO 1998, 2010). Today, over 1,750 genebanks have been established worldwide, with 7.4 million accessions maintained as *ex situ* collections in either seed banks, field collections, and *in vitro* and cryopreservation conditions. Out of these, 89% are held in national genebanks and 130 genebanks hold more than 10,000 accessions (FAO 2010). It is significant to note that as much as 45% of germplasm is held by only 7 countries. About half of all accessions maintained in *ex situ* collections are advanced cultivars or breeders' lines, while just over one third of them are made up by landraces, or old cultivars, and about 15% are wild relatives of crop species, weedy plants or wild plants. Only a third of all accessions are characterized. There is obviously a gap in the collections regarding minor crops and underutilized species, in particular landraces and wild relatives of crops from the respective crops centres of diversity and cultivation are underrepresented in genebanks.

Although reportedly over-represented, a large part of the genetic diversity of major food crops is stored in *ex situ* collections. The exact proportion is still uncertain, but estimates suggest that more than 70% of the genetic diversity of some 200-300 crops is already conserved in genebanks (Khoury *et al*. 2010). In addition there are over 2 500 botanic gardens maintaining samples of some 80 000 plant species (FAO 2010). However, regeneration of genebank accessions remains a major problem, threatening collections (FAO 1998). In the past decade there have been significant advances made in regenerating collections at risk, in part due to efforts made by the Global Crop Diversity Trust (CGDT) in supporting regeneration programmes of globally important priority genebank collections for 22 priority crops for which crop-specific regeneration guidelines have recently been produced (Khoury *et al*. 2010).

As per international *Genebank Standards* of the FAO, each genebank should have provision of conservation of safety duplicates of potentially unique germplasm at a distant place far from the location of the genebank. This is required for preparedness in unforeseen and extreme situations such as nuclear or civil war, terrorists disruptions or any other catastrophic failure. At the global level, the 'Svalbard Global Seed Vault (SGSV)', is a state-of-the-art facility built inside a mountain in a man-made tunnel on the frozen Norwegian island of Spitsbergen, 1 307 km from North Pole. The area's permafrost keeps the vault below the freezing point of water and the seeds are protected by 1-metre thick walls of steel-reinforced concrete. The SGSV was commissioned in 2008. The natural temperature is about -6°C, and -20°C temperature is maintained with the help of power back up.

It has a capacity to store 3.5 million accessions. Currently, 774 601 samples are deposited at SGSV by 53 genebanks, estimated to cover more than one third of the globally distinct accessions of 156 crop genera stored in genebanks (Westengen *et al.* 2013). The establishment of the SGSV serves as the ultimate safety net for seeds samples from the world's most important collections (Khoury *et al*. 2010).

PGR CONSERVATION IN INDIA

India's rich cultural and ecological diversity has been the mainstay of several traditional farming systems in the country for many centuries. These traditional systems were critical in developing, maintaining and using the vast PGR diversity. They were rooted in the philosophy of 'conservation agriculture'. In India, activities on PGR were set in motion by late Dr B P Pal who emphasized the importance of germplasm augmentation and utilization in crop improvement, in his classic paper "Search for new genes" (Pal 1937). The scheme for 'Plant Introduction' was initiated in 1946 in the Botany Division of the then Imperial Agricultural Research Institute (Dhillon *et al.* 2001). This was later upgraded to 'Division of Plant Introduction' in 1956 and thereafter an independent institute 'National Bureau of Plant Introduction' was established in August 1976 that was later renamed as 'National Bureau of Plant Genetic Resources (NBPGR)'.

The National Genebank (NGB) was established at NBPGR during 1985-86 to carry out PGR conservation holistically. In addition to field genebanks, it had three components (i) seed genebank to conserve the genetic resources of seed crops at -18°C in long term storage (LTS) modules, (ii) *in vitro* genebank to conserve the genetic resources of horticultural crops in the form of tissue culture at 4-25°C, and (iii) cryobank to conserve the genetic resources of recalcitrant seed (difficult-to-store) and clonally propagated crops at -196°C (in liquid nitrogen). In 1996, the infrastructure of the NGB was greatly expanded and established the state-of-the-art NGB. Presently, in the NGB, 3 98 780 accessions belonging to 1 580 species are conserved in the LTS; 10 008 accessions of 729 species are conserved in the cryobank; 1 916 accessions belonging to 132 vegetatively propagated plant species under *in vitro* conditions; and 51 473 accessions are grown in the field genebanks. In terms of total number of accessions conserved *ex situ*, the Indian NGB ranks third in the world, after China and USA. The NGB has the second highest collection of rice (11% of the world total), fourth highest in wheat (4% of the world total) and sorghum (7% of the world total), and fifth highest collection of pearl millet (5% of the world total) (FAO 2010).

CONCEPTUALIZATION OF GENEBANK STANDARDS

In the early 1970s, FAO and the International Board for Plant Genetic Resources (IBPGR), Rome [later re-christened the 'International Plant Genetic Resources Institute' (IPGRI) and presently known as 'Bioversity International'] collaborated to strengthen national capabilities in *ex situ* conservation of PGR and also to promote development of an international network of genebanks. During the 1980s, FAO remained the principal forum in which the developing countries tried to pursue for an inter-governmental legal framework to set global standards and rules for the conservation and exchange of PGR. To facilitate this activity during 1982 to 1985, IBPGR published technical handbooks related to design of seed genebanks and scientific methods for seed conservation, (Cromarty *et al*. 1982, Ellis *et al.* 1985a, 1985b). In the meantime, FAO established an inter-governmental Commission on Plant Genetic Resources (CPGR) in 1983 which adopted a non-binding 'International Undertaking on Plant Genetic Resources' (IUPGR), aimed at promoting the conservation and use of PGR, ensuring access to them without undue restriction (www.fao.org/nr/cgrfa/cgrfa-home/en/). The CPGR was later renamed as 'Commission on Genetic Resources for Food and Agriculture (CGRFA). The CGRFA is a unique inter-governmental global forum, where countries that are donors or users of germplasm, funds and technology, can discuss, on an equal footing, matters related to genetic resources.

During the Fourth Regular Session of the CPGR held in 1991, the Commission recorded the need for "establishment of technical *standards* for genebanks", under the auspices of FAO (ftp.fao.org/docrep/fao/meeting/015/aj419e.pdf). Subsequently, an 'FAO/IBPGR Experts Consultation Group on *Genebank Standards*' was convened in 1992 to discuss and update the 'Handbook of Seed Technology for Genebanks' that IBPGR had published in 1985 (Ellis *et al*. 1985b). The Fifth Session of the CPGR held in 1993 considered the *Genebank Standards* that had been prepared by the FAO/IBPGR expert group and endorsed them, in order that they might acquire international value and be more easily adopted by countries. These standards which were non-binding and voluntary in nature, were published in 1994 and given wide diffusion (FAO/IPGRI 1994). At that time the standards pertained solely with the storage of seeds of orthodox species.

REVISION OF GENEBANK STANDARDS

A need was felt by the CGRFA for revising the *Genebank Standards* (FAO/IPGRI 1994) due to significant progress in science and technology related to seed storage, biotechnology and communications. Additionally, changes in the policy issues related to genetic resources, especially adoption of international instruments such as the CBD, ITPGRFA and the International Plant Protection Convention (IPPC 2005), also required commensurate harmonization in the standards. Hence, during the Twelfth Regular Session of the CGRFA held in 2009**,** the Commission agreed on the need for revising the *Genebank Standards* (www.fao.org/nr/cgrfa/cgrfa-meetings/cgrfa-comm/twelfth-reg/en/). A consortium of relevant bodies comprising the CGRFA, CGIAR and its associated IARCs, GCDT, the ITPGRFA, IPPC, and other relevant institutions, reviewed the standards

for consideration by the Commission's 'Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture' (ITWG-PGRFA), at Thirteenth Regular Session (www.fao.org/nr/cgrfa/cgrfa-meetings/cgrfa-comm/twelfth-reg/en/).

The first draft of the revised *Genebank Standards* was prepared by the Bioversity International and FAO together with GCDT, ITPGRFA and IPPC and opened for discussion in an Expert Consultation Meeting held during 6-8 September 2010 at Rome, Italy. The Senior Author participated (from India) along with other genebank experts from Bioversity International, GCDT and ITPGRFA and other countries e.g. Brazil, China, Germany, Netherlands, Syria, Taiwan, Turkey, United Kingdom, United States of America and Zambia. During the meeting, the overall approach of the *Draft Updated Genebank Standards* and the underlying principles for maintaining genebank were discussed. The consultations provided valuable inputs such that current scientific knowledge and changes in the conditions for *ex situ* conservation of orthodox seeds could be reflected in the revised version (Tyagi and Agrawal 2013). In view of scientific and technological advancements, deliberations for standards related to almost all aspects of management of PGR including germplasm acquisition, processing, storage, viability monitoring, regeneration, characterization, documentation, distribution, personnel training and genebank security were held. A view of all the experts was taken whether to develop the standards for *in vitro* conservation and cryopreservation of vegetatively propagated crops and cryopreservation of recalcitrant species. It was agreed by all the experts that *Standards* should also be developed for *In Vitro* Genebanks, Cryogenebanks and Field Genebanks to maintain the germplasm scientifically and uniformly all over the world (Tyagi and Agrawal 2013).

This draft was considered by the ITWG-PGRFA of the CGRFA in its meeting held in April 2011. The Commission appreciated the technical quality and presentation of the draft standards, and requested FAO to also provide draft standards on germplasm "evaluation" in order to achieve more comprehensiveness. The Commission requested the ITWG-PGRFA to finalize the *Draft Revised Genebank Standards,* for endorsement by the CGRFA in its next meeting. Thus, the document *Draft Genebank Standards for Plant Genetic Resources for Food and Agriculture* (www.fao.org/docrep/meeting/027/mf804e.pdf) was endorsed by the CGRFA during the Fourteenth Regular Session held from 15-19 April 2013. It has been recently published as *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (FAO 2013).

KEY FEATURES OF REVISED GENEBANK STANDARDS

The revised *Genebank Standards* encompass guidelines for conserving orthodox, non-orthodox seeds and vegetatively propagated plants, whereas earlier only standards for orthodox seeded plants were given. Another important change in the revised text is that only one 'standard' has been used in contrast to two levels ('preferred' and 'acceptable') prevalent earlier. This is mainly to avoid ambiguity or unnecessary duplications and also to optimize the use of limited resources. The text of the revised *Genebank Standards* comprises two major parts. The first part gives fundamental principles of *Genebank Standards* with an overview for effective and efficient management of genebanks. The key principles at the core of genebank operation are the maintenance of germplasm identity, viability and genetic integrity, and the promotion of access including associated information to facilitate use (FAO 2013). The second part provides the detailed standards for three types of genebanks namely: seed banks, field genebanks and *in vitro/*cryopreservation genebanks. For the Genebank Standards for Orthodox Seeds, aspects related to acquisition of germplasm, seed drying and storage, viability monitoring, regeneration, characterization, evaluation, documentation, distribution, safety duplication and security/personnel have been covered. In case of Field Genebank, standards for the choice of location, acquisition of germplasm, establishment of field collections, field management, regeneration and propagation, characterization, evaluation, documentation, distribution, security and safety duplication are included. Finally Genebank Standards for *in vitro* Culture and Cryopreservation comprise acquisition of germplasm, testing for non-orthodox behaviour and assessment of water content, vigour and viability, hydrated storage for recalcitrant seeds, *in vitro* culture and slow-growth storage, cryopreservation, documentation, distribution and exchange, security and safety duplication (FAO 2013).

As in the earlier edition published in 1994, these *Standards* are basically targets to aim for and remain non-binding and voluntary in nature (Tyagi and Agrawal 2013, FAO 2013). The revised *Genebank Standards* take into account the changes in *ex situ* conservation conditions, diversity in storage requirements, purpose and period of germplasm conservation, ranging from temperate to tropical provenances. Table 1 provides a comparison of some key features between the original and revised *Genebank Standards.* Field genebanking is the most commonly used method for non-orthodox seed producing plants, for plants that produce very few seeds, and vegetatively propagated and/or plants that require a long life cycle to generate breeding and/or planting materials. The key features of the *Standards* for above category plants are highlighted in Table 2. The standards for *in vitro* culture and cryopreservation are broad and generic in nature, due to the marked variation among non-orthodox seeds and vegetatively propagated plants are presented in Table 3.

IMPLICATIONS OF REVISED GENEBANK STANDARDS

Genebanks exist throughout the world and they collect, catalogue, store and protect as many species of plants as possible. These genebanks are useful to plant breeders

Table 1 Comparison of some key features of *Genebank Standards* (1994) and Revised *Genebank Standards* (2013)

Feature	Genebank Standards (1994)	Revised Genebank Standards (2013)
Crops coverage	Orthodox seeds	Orthodox seeds, non-orthodox seeds and vegetatively propagated plants
Activities covered for seed genebanks	Seed drying and storage; viability monitoring; regeneration; documentation; distribution, safety duplication; and security/personnel	Germplasm acquisition; seed drying and storage; viability monitoring; regeneration; characterization; evaluation; documentation; distribution; safety duplication; and security/personnel
Activities covered for field genebanks	Not covered	Choice of location; germplasm acquisition; establishment of field collections; field management; regeneration and propagation; characterization; evaluation; documentation; distribution; security; and safety duplication
Activities covered for *in vitro* genebanks and cryogenebanks	Not covered	Germplasm acquisition; testing for non-orthodox behaviour and assessment of water content; vigour and viability; hydrated storage for recalcitrant seeds; *in vitro* culture and slow growth storage; cryopreservation; documentation; distribution and exchange; security; and safety duplication
Definition of 'standard'	Acceptable standards – in many cases minimal but adequate (at least for short-term) Preferred standards – a higher and, thus, safer standard	One standard – The lowest level of performance of a routine genebank operation below which there is a high risk of losing genetic integrity (e.g. a probability of 5% or more of losing an allele in an accession over the storage period)
Germplasm acquisition	Not covered	• All seed samples are acquired legally with technical documentation in line with the ITPGRFA • Have a minimum of associated data (FAO/IPGRI multi-crop passport descriptors) • Period between seed collecting and transfer is as short as possible • Minimum size of a seed sample must capture 95% alleles in the sampled population
Seed drying conditions	Drying at 10-25°C and 10-15% RH	• Seeds to be dried to equilibrium in a controlled environment of 5-20°C and 10 -25 % RH, depending upon species
Seed storage conditions	• Acceptable : Sub-zero temperatures (<0°C) with 3-7% seed moisture content (depending upon species) • Preferred: -18°C or cooler with 3-7% seed moisture content (depending upon species) • Use of any type of sealed moisture-proof containers	• Most original-samples and safety duplicate samples should be stored under long-term conditions (base collections) at a temperature of -18 ± 3°C and RH of 15 ± 3% • For medium-term conditions (active collection) samples should be stored under refrigeration at 5-10°C and RH of 15 ± 3% • Suitable air-tight container for LTS; for active collection non-airtight containers may be used
Seed viability	• Carried out at (or soon after) receipt and subsequently at intervals during storage • Initial germination test should be carried out on a minimum of 200 seeds drawn at random from the accession • Germination should exceed 85% for most cereals and 75% some vegetables and lower for some wild or forest species	• The initial seed viability test should be conducted after cleaning and drying the accession or at the latest within 12 months after receipt of the sample at the genebank • ISTA (2008) standards to be used for determining no. of seeds for initial germination testing - 200, 100 or less, depending on species, and in replications • Germination should exceed 85% for crop species; for some wild or forest species, lower (70%) germination may be accepted • Viability monitoring test to be set at 1/3 of time predicted for viability to fall to 85% of initial viability
Regeneration	• To be carried out when seed viability falls to 85% of the initial value • Desirable to use 100 plants or more for regeneration to avoid the probability of large losses of alleles	• Viability drops below 85% of the initial viability. The most-original-sample should be used to regenerate those accessions • The sample size of the accession to-be-regenerated contains a minimum number of plants which capture at least 95% of alleles with a minimum frequency of 0.05 • Regenerated material should contain less than 1% of contamination. • 50 seeds of most-original-sample is archived in LTS

Contd.

Table 1 *Contd.*

Feature	Genebank Standards (1994)	Revised Genebank Standards (2013)
Characterization	It is preferred that characterization and evaluation data on the accessions should also be held by base collections or be readily available from other sources	• Around 60% of accessions should be characterized within 5 to 7 years of acquisition or during the first regeneration cycle • Characterization should be based on standardized and calibrated measuring formats and characterization data follow internationally agreed descriptor lists and are made publicly available
Evaluation	Not covered	• Evaluation data on genebank accessions should be obtained for traits that are included in internationally agreed crop descriptor lists. They should conform to standardized and calibrated measuring formats. • Data should be obtained for as many accessions as possible, through laboratory, greenhouse and/or field analysis. • Evaluation trials should be carried out in at least three environmentally diverse locations and data collected over at least three years
Documentation	Each accession should be accompanied by available passport and management data and mode of reproduction (if known)	• Passport data of 100% of the accessions should be documented using FAO/IPGRI multi-crop passport descriptors · All data and information generated in the genebank relating to all aspects of conservation and use of the material should be recorded in a suitably designed database.
Distribution and exchange	• A sufficient number of viable seeds should be sent out in order to provide a genetically representative sample of the accession • Seeds should be accompanied by adequate germination, passport and evaluation data (if required) • Quarantine and other seed health requirements must be satisfied	• Seeds should be distributed in compliance with national laws and relevant international treaties and conventions • Seed samples should be provided with all relevant documents required by recipient country • The time span between receipt of a request for seeds and the dispatch of the seeds should be kept to a minimum • For most species a sample of a minimum of 30-50 viable seeds should be supplied for accessions with sufficient seeds in stock. For accessions with too little seed at the time of request and in the absence of a suitable alternative accession, samples should be supplied after regeneration/multiplication, based on a renewed request
Safety duplication	Not covered	• A safety duplicate sample for every original accession should be stored in a geographically distant area, under the same or better conditions than those in the original genebank • Each safety duplicate sample should be accompanied by relevant associated information
Security and personnel	• Every effort must be made to ensure the safety and security of the germplasm in collections through adequate construction, maintenance and security controls of the installation • Equipment should undergo regular preventative maintenance and trained maintenance personnel are essential for this • It should be ensured that continuous power supply, fire precautions and security arrangements are in place	• A genebank should follow the local Occupational Safety and Health requirements and protocols where applicable • A genebank should employ the requisite staff (trained) to fulfil all the routine responsibilities to ensure that the genebank can acquire, conserve and distribute germplasm according to the standards • A genebank should have a risk management strategy in place which includes, *inter alia*, measures against power cut, fire, flooding and earthquakes

involved in developing new climate resilient varieties. They can also provide a resource for restoration of key species after natural or man-made catastrophes. The draft revised *Genebank Standards* are voluntary but have a universal value and utility in guiding genebank management for seeds (orthodox and non-orthodox) and vegetatively propagated crops. It provides a framework for effective and efficient management of genebanks, and the basis for establishing the norms and standards essential for the smooth operation of a genebank. It can be used by genebank curators as a source of guidance for developing standard operating procedures. The standards would also be very helpful for developing Quality Management Systems in genebanks which are lacking in most of the national genebanks. After

Table 2 Highlights of revised *Genebank Standards* (2013) for field genebanks*

Feature	Standards
Choice of location	• Should be similar to the agro-ecological conditions where the collected plant materials were normally grown or collected • With minimum risks from natural and manmade disasters/hazards • Should have a secured land tenure and be easily accessible with adequate facilities for propagation and quarantine
Germplasm acquisition	• Accessions should be legally acquired, with relevant technical documentation and at least a minimum of associated passport descriptors • Propagating material should be collected from healthy growing plants at an adequate maturity stage to be suitable for propagation. • Period between collecting, shipping and processing and then transferring to the field genebank should be as short as possible • Exotic samples should pass through the relevant quarantine process before being incorporated into the field collection
Establishment of collection	• Sufficient number of plants should be maintained to capture the genetic diversity and ensure the safety of an accession • A field genebank should have a clear map showing the exact location of each accession in the plot • Appropriate cultivation practices should be followed
Field management	• Plants and soil should be regularly monitored for pests and diseases. • Appropriate cultivation practices should be performed to ensure satisfactory plant growth. • Genetic identity of each accession should be monitored by ensuring proper isolation of accessions wherever appropriate, avoiding inter-growth of accessions, proper labelling and field maps and periodic assessment of identity using morphological or molecular techniques
Regeneration and propagation	• Each accession should be regenerated when the vigour and/or plant numbers have declined to critical levels and ensure the diversity and genetic integrity is maintained • True-to-type healthy plant material should be used for propagation • Information regarding plant regeneration cycles and procedures including the date, authenticity of accessions, labels and location maps should be properly documented and included in the genebank information system
Characterization	• All accessions should be characterized, using a representative number of plants for each accession • Accessions should be characterized morphologically using internationally used descriptor lists where available. Molecular tools are also important to confirm accession identity and trueness to type
Evaluation	• Evaluation data should be obtained for traits of interest and in accordance with internationally used descriptor lists where available. • The methods/protocols, formats and measurements for evaluation should be properly documented with citations. Data storage standards should be used to guide data collection. • Evaluation trials should be replicated (in time and location) as appropriate and based on a sound statistical design.
Documentation	• Passport data for all accessions should be documented using the FAO/IPGRI multi-crop passport descriptors. In addition accession information should also include inventory, map and plot location, regeneration, characterization, evaluation, orders, distribution data and user feedback· All data should be stored and changes updated in an appropriate database system and international data standards adopted
Distribution and exchange	• All germplasm should be distributed in compliance with national laws and relevant international treaties and conventions • All samples should be accompanied by all relevant documents required by the donor and the recipient country. • Associated information should accompany any germplasm being distributed. The minimum information should include an itemized list, with accession identification, number and/or weights of samples, and key passport data.
Security and safety duplication	• Physical and biological risk management strategy should be implemented as required· Follow the local Occupational Safety and Health (OSH) requirements and protocols· Every field genebank accession should be safety duplicated at least in one more site and/or backed up by an alternative conservation method/ strategy such as *in vitro* or cryopreservation where possible

*Standards for field genebank were not covered in original *Genebank Standards* published in 1994

Table 3 Highlights of revised *Genebank Standards* (2013) for *in vitro* culture and cryopreservation*

Feature	Standards
Germplasm acquisition	• All germplasm accessions should be legally acquired, with relevant technical documentation and accompanied by at least a minimum of associated passport data. • Only material in good condition and of consistent maturity status should be collected, and the sample size should be large enough to make genebanking a viable proposition. • Material should be transported to the genebank in the shortest possible time and in the best possible conditions • All incoming material should be treated by a surface disinfectant agent to remove all adherent microorganisms and handled so that its physiological status is not altered, in a designated area for reception
Testing for non-orthodox behaviour and assessment of water content, vigour and viability	• Storage category of the seed should be determined immediately by assessing its response to dehydration • Water content should be determined individually, on separate components of the propagule, and in a sufficient number of plants (at least 10 seeds) • Vigour and viability should be assessed by germination tests and in a sufficient number of individuals (at least 20). Viability should not be not less than 80% in a sample. • During experimentation, cleaned seed samples should be stored under conditions that do not allow any dehydration or hydration
Hydrated storage of recalcitrant seeds	• Hydrated storage should be carried out under saturated RH conditions, and seeds should be maintained in air-tight containers, at the lowest temperature that they will tolerate without damage (6 ± 2 °C for temperate and 16 ± 2° for tropical/subtropical species) • All seeds should be disinfected prior to hydrated storage and infected material should be eliminated • Stored seeds must be inspected and sampled periodically to check if any fungal or bacterial contamination has occurred, and whether there has been any decline in water content and/or vigour and viability
In vitro culture and slow growth storage	• Identification of optimal storage conditions for *in vitro* cultures must be determined according to the species (normally 0 to 5°C for temperate and 15 to 20 °C for tropical species) • Material for *in vitro* conservation should be maintained as whole plantlets or shoots, or storage organs for species where these are naturally formed • A regular monitoring system for checking the quality of the *in vitro* culture in slow growth storage, and possible contamination, should be in place
Cryopreservation slow growth storage	• The explants should be of highest possible quality, and allow onward development after excision and cryopreservation • Each step in the cryo-protocol should be tested individually and optimized in terms of vigour and viability in retention of explants • Means should be developed to counteract damaging effects of reactive oxygen species (ROS), at excision and all subsequent manipulations • Following retrieval, explants should be disinfected using standard sterile procedures
Documentation	• Passport data for all accessions should be documented using the FAO/IPGRI multi-crop passport descriptors. In addition accession information should also include inventory, orders, distribution and data user feedback • Management data and information generated in the genebank should be recorded in a suitable data base, and characterization and evaluation data (C/E data) should be included when recorded· Data from should be stored and changes updated in an appropriate database system and international data standards adopted
Distribution and exchange	• All germplasm should be distributed in compliance with national laws and relevant international conventions • All samples should be accompanied by a complete set of relevant documents required by the donor and the recipient country • The supplier and recipient should establish the conditions to transfer the material and should ensure adequate re-establishment of plants from *in vitro*/cryopreserved material·
Security and safety duplication	• Risk management strategy should be implemented and updated as required that addresses physical and biological risks identified in standards including issues such as fire, floods and power failures • A genebank should follow the local Occupational Safety and Health requirements and protocols. The cryo-section of a genebank should adhere to all safety precautions associated with using LN

Contd.

Table 3 *Contd.*

Feature	Standards
	• Depletion of LN in a cryo-storage vat or LN freezer would lead to irretrievable loss of all samples. If not detected, electrical or other failure of the temperature control system in a growth room could cause overheating with consequent loss of *in vitro* material • A safety duplicate sample of every accession (accompanied by relevant documentation) should be stored in a geographically distant genebank under best possible conditions

*Standards for in vitro culture and cryopreservation were not covered in original *Genebank Standards* published in 1994

publication of by FAO, the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* will be available to all concerned like genebank curators, policy makers, researchers and all other relevant stakeholders involved in genebanking. Although, adoption of these standards are voluntary, but if all genebanks adopt these standards, it will (i) ensure efficient, safe and cost-effective conservation of PGR under optimal conditions for perpetuity, (ii) enhance the quality management system of genebanks, and (iii) increase the confidence amongst the users for exchange and use of quality germplasm in world over crop improvement programmes.

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