Chapter 5

Field genebank standards

5.1 Standards for choice of location of the field genebank

Standards

5.1.1 The agro-ecological conditions (climate, elevation, soil, drainage) of the field genebank site should be as similar as possible to the environment where the collected plant materials were normally grown or collected.

5.1.2 The site of the field genebank should be located so as to minimize risks from natural and manmade disasters and hazards such as pests, diseases, animal damage, floods, droughts, fires, snow and freeze damage, volcanoes, hails, thefts or vandals.

5.1.3 For those species that are used to produce seeds for distribution, the site of the field genebank should be located so as, to minimize risks of geneflow and contamination from crops or wild populations of the same species to maintain genetic integrity.

5.1.4 The site of the field genebank should have a secured land tenure and should be large enough to allow for future expansion of the collection.

5.1.5 The site of the field genebank should be easily accessible to staff and supplies deliveries and have easy access to water, and adequate facilities for propagation and quarantine.

Context

Considering the long-term nature of a field genebank, the selection of an appropriate site for its location is critical for the successful conservation of germplasm. There are many factors that need to be taken into account when selecting a site for a field genebank including appropriate agro-ecological condition for the plants being conserved at the site, associated natural and manmade disasters, secure long-term land tenure, accessibility of the site for staff and availability of water resources.

Technical aspects

Plants will grow strong and healthy when planted under appropriate agro-ecological conditions. Field genebanks are particularly vulnerable to losses caused by poor adaption of material that has originated in environments that are very different from that of the genebank location. The selected site for the field genebank should have an environment and soil type best suited for the species to reduce the risk of poor adaptation. One solution to poor adaptation is to take a decentralized approach to genebank management, i.e. to collocate the collections in different agro-ecologies rather than in a centralized genebank. Accessions of similar adaptation are kept together in a station located in an agro-environment similar to their origin or similar or near to their natural habitat. The natural conditions of the original environment can be simulated by providing higher shade intensity or drainage, for example for crop wild relatives that originated in natural forests versus cultivated plants that are adapted to higher light intensity.

Avoidance of pests and diseases and insect vectors are very important for field collections. If possible, the field genebank should be located in a location that is free from major pathogenic diseases and pests or away from known infected regions for fungi and virus to reduce risk and management costs related to plant protection and ensure a clean source of material for distribution. Soils should be checked before planting to ensure they are free from fungi, termites or other soil-borne parasites and appropriate treatment provided to clean soil before planting. Where this is not possible, the selected site should be located at some distance from fields of the same crop to reduce threats from insect pests and diseases and diseased plants should be removed with a vigorous roguing programme. If possible, maintain collections in areas with a hot and dry climate, which is less favourable for vector movement, pests and diseases. Further, the bringing together of large numbers of plants susceptible to disease may severely enhance the risk of disease outbreaks. Such large collections of single genera deserve particular scrutiny from a disease point of view.

The assessment of risk from natural disasters such as floods, fires, snow/ice, volcanoes, earthquakes and hurricanes is an important criterion for ensuring the physical safety of collections. In addition, physical security and potential of anthropogenic threats such as theft and vandalism should be taken into account. These characteristics should be considered when locating and designing a field genebank to help reduce loss of germplasm (see also Standards on safety).

Insect netting and cages can be used for protection against insect or bird damage for smaller plants. Out-crossing species such as fruit trees with recalcitrant seeds or grasses that are grown for seed as well as maintained as plants require isolation from potential pollinators. Selecting a site away from crop stands or wild populations of the same species to avoid gene flow or weed contamination is important for ensuring genetic integrity in these species. Recommended isolation distances, isolation cages or pollination control measures should be established and followed for propagation. Crop-specific information about isolation distance in regenerating accessions is available on the Crop Genebank Knowledge Base (see references).

A field genebank should be located in a secure site with a long-term agreement and guaranteed or gazetted land tenure and funding, taking into consideration the development plan for the area. The land-use history can give information about the pest or weed status of the land and the quantity of fertilizer used. High use of fertilizer in previous years could affect the growths of root and tubers. High residual fertilizer for example, can prevent tuber development in sweet potatoes. Drought stress can be avoided when the availability of adequate rainfall or water supply for supplementary irrigation is included as a selection criterion. Apart from land-use history, it is recommended to include measures that can be taken to ascertain and correct the physical and nutritional status of soils. This basically entails soil physical and chemical analysis followed by subsequent corrective measures. Areas with high potassium usage need to be balanced with supplemental calcium and magnesium applications, especially for tropical fruit trees.

The size of the chosen site should provide sufficient space for the type of species to be conserved as well as for possible future expansion when the collection grows, especially in the case of perennial species. Required space for tree crops can be considerable. Also, sufficient space should be available to accommodate annuals that require continuous replanting and rotation between plots to avoid any possible contamination from previous plantings, as well as rotation of annuals and perennials to control disease and manage soil fertility. Sufficient and appropriate storage facilities are required if plant material needs to be stored after harvest before the next planting.

Easy physical access to germplasm will aid monitoring and plant management. The site should be suitable for access of labour and machinery for mulching, fertilizer and pesticide applications and have access to adequate year-round irrigation, propagation, and *in vitro* or cryopreservation facilities as required. A good security system should be in place to avoid theft or damage to germplasm and facilities.

Contingencies

When accessions from different eco-geographical origins are planted in one location, careful attention by the curatorial field staff is required to monitor the reproductive phenology and seed production, and identify and transfer poorly adapted accessions to possible alternative sites, greenhouses, or *in vitro* culture to avoid genetic loss. Special management practices may be required for some accessions. Protected areas such as screenhouses or cages may be required to protect the plants from predators.

SELECTED REFERENCES

Anderson, C.M. 2000. *Citrus germplasm resources and their use in Argentina, Brazil, Chile, Cuba and Uruguay*. Proc. IX ISC. Vol I: 123–125, Orlando, Florida, USA.

Anderson, C.M. 2008. *Recursos genéticos y propagación de variedades comerciales de cítricos*. XII Simposium Internacional de Citricultura. Tamaulipas, México.

Borokini, T.I, Okere, A.U., Giwa, A.O., Daramola, B.O. & Odofin, T.W. 2010. Biodiversity and conservation of plant genetic resources in field genebank of National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria. *International Journal of Biodiversity and Conservation*, 2(3): 037–050.

Davies, F.S. & Albrigo, L.G. 1994. *Citrus*. Wallingford, UK, CAB International.

Gmitter, F.G. & Hu, X.L. 1990. The possible role of Yunnan, China, in the origin of contemporary citrus species (Rutaceae). *Economic Botany*, 44: 267–277.

Said Saad, M. & Rao, V.R., eds. 2001. *Establishment and management of field genebank training manual*. Serdang, Malaysia, IPGRI-APO.

SGRP-CGIAR. Crop Genebank Knowledge Base (available at: http://cropgenebank.sgrp.cgiar.org/).

5.2 Standards for acquisition of germplasm

Standards

5.2.1 All germplasm accessions added to the genebank should be legally acquired, with relevant technical documentation.

5.2.2 All material should be accompanied by at least a minimum of associated data as detailed in the FAO/Bioversity multi-crop passport descriptors.

5.2.3 Propagating material should be collected from healthy growing plants whenever possible, and at an adequate maturity stage to be suitable for propagation.

5.2.4 The period between collecting, shipping and processing and then transferring to the field genebank should be as short as possible to prevent loss and deterioration of the material.

5.2.5 Samples acquired from other countries or regions within the country should pass through the relevant quarantine process and meet the associated requirements before being incorporated into the field collection.

Context

Acquisition is the process of collecting or requesting such materials for inclusion in the field genebank, together with related information. The nature of plants with recalcitrant seed and vegetatively propagated plants requires special attention when acquiring germplasm for conservation in field genebanks. The propagules required for establishing a field genebank may come in different forms such as seeds, cuttings, tubers, corms, scionwood, tissue cultures, graftwood, or cryopreserved material. The plant materials may be obtained from existing genebanks, research and breeders' collections, landraces and cultivated forms grown by farmers and from plant explorations/expeditions. The relevant national and international regulations, such as phytosanitary/quarantine laws and national laws for genetic resources access, the IPPC, ITPGRFA, CBD, and any others that govern the movement and acquisition of germplasm, must be taken in to account.

Technical aspects

Adherence to Standard 5.2.1 will allow the safe movement of germplasm both from collection sites within the country and outside the country to the site hosting the genebank. When germplasm material is collected *in situ,* it is important to adhere to the national regulations, which normally require that collecting permits are obtained from relevant national authorities. If the collection is from farmers' fields or community areas prior informed consent may be required in accordance with relevant national, regional or international law. If germplasm material has to be exported from a country, an appropriate material transfer agreement should be used. In the case of PGRFA, the export can be accompanied with the SMTA or other similar permits in compliance with national regulations of access and benefit-sharing. Import permit regulations, which specify phytosanitary and any other import requirements, must be sought from the relevant national authority of the receiving country.

During the acquisition phase, it is important to ensure that passport data for each accession are as complete as possible. Especially, georeferenced data are very useful as they give a precise account of the location of the original collecting sites and help to identify accessions with specific adaptive traits in accordance to the agro-climatic conditions of the original collecting sites. Passport data are crucial in identifying and classifying each accession and will function as an entry point in selecting and using the accession. Appropriate collecting forms should be used to capture comprehensive collecting data. These forms should include information such as the initial taxonomic classification of the sample, the latitude and longitude of the collecting site, a description of the habitat of the collected plants, the number of plants sampled and other relevant data that are important for proper conservation, as provided in the FAO/Bioversity multi-crop passport descriptors (Alercia *et al*., 2012). Very useful additional information, such as cultural practices, methods of propagation, history and origin, and uses can be obtained with interviews when material is collected from farmer fields. Whenever possible, a herbarium voucher

specimen collected from the same population as the samples, should be kept as a reference collection, and a record should be made of the method and reason for acquisition.

In the case of donations (from research programme or genebank), the taxonomic classification, donor name, donor identification number, and names of germplasm in addition to the available passport data should be provided. Adequate information about how the germplasm received was maintained, including pedigree or lineage information, as well as chain of custody information where available should be sought from the donor. Materials should be assigned a unique identification number (either temporary or permanent, according to the practice used in the genebank) that will link the material to the passport data and any other collected information, guaranteeing the authenticity of the sample.

Although it is not possible to ensure that plant material collected *in situ* is in completely healthy condition (no diseases and insect pest infestation) it is important that as far as possible propagules are collected from plants that appear healthy, devoid of disease and insect pest infestations or damage. Clean material acquired from certified sources should be stored in a screenhouse, to prevent insects from infesting clean plants and spreading pathogens. During collecting, the collector should also avoid the depletion of the natural population targeted for collecting. It may also be useful to repeat sampling from a particular site to maximize capture of genetic variability that may be present at various points in time (Guarino *et al*., 1995). In the collection phase of vegetatively propagated perennial samples, especially when collecting shoots suitable for taking cuttings or grafting, it would be desirable to stimulate the formation of adequate shoots by scoring the trunk or the branches; these shoots could then be collected during a second visit.

It is important to highlight that the time taken to transfer the original genetic resource from the time of collecting to the genebank is critical. This is especially true for species that produce recalcitrant seeds and clonal stock, which do not retain their viability for very long and for vegetative propagules that decay easily. In some cases, germplasm material may need to be shipped over long distances, as the case may be when the material is acquired from other countries. Due consideration of the shipping period including transit and processing period, should be taken into account and appropriate measures taken to ensure that the material reaches the destination genebank in good condition. It is also important to properly prepare the propagules (scion woods, seeds or cuttings) to improve viability during postal or parcel transportation. For example, recalcitrant seeds and scions should be packed in sterile cotton or other suitable material in a perforated plastic bag to ensure sufficient air exchange. Seeds should be protected from crushing by mechanical mail sorter in rigid cushioned shipping. For scion wood, the two cut ends of the cleaned scion should be wrapped using a para-film strip to reduce moisture loss. Collections sent from tropical areas need to be mindful of high temperatures during transportation.

Given that field collections cannot accommodate many samples (see Standards for establishment of collection), the sample size for collecting will usually be limited compared to orthodox seeds. Nevertheless, all attempts should be made at maximizing the collection for the target population's genetic diversity. In addition, in collecting for a field genebank, the collector will need to take decisions on how many plants within a population can practically be collected. The actual figure will largely depend on the breeding system of the plant, the plant type and the part of the plant being collected.

Contingencies

Collecting should not take place without meeting the legal requirements, especially if the germplasm is taken out of the country of collecting afterwards. In the event that materials cannot be taken out of the country due to phytosanitary requirements, efforts should be made to establish field collections in the country of origin and/or to establish *in vitro* cultures that are more amenable for export. Allowances in terms of the sample size should be made for wild and rare species where propagation material might not be available in optimal conditions or quantity.

SELECTED REFERENCES

Alercia, A., Diulgheroff, S. & Mackay, M. 2012. FAO/Bioversity *Multi-Crop Passport Descriptors* (MCPD V.2). Rome, FAO and Bioversity International (available at: http://www.bioversityinternational.org/uploads/tx_news/1526.pdf).

Bioversity International/ Food and Fertilizer Technology Center/TARI-COA (Taiwan Agricultural Research Institute-Council of Agriculture). 2011. *A training module for the international course on the management and utilisation of field genebanks and* in vitro *collections*. Fengshan, Taiwan, TARI.

Brown, A.H.D. & Hardner, C.M. 2000. *Sampling the genepools of forest trees for ex situ conservation. In* A. Young, D. Boshier & T. Boyle. *Forest conservation genetics. Principles and practice*, pp.185–196. CSIRO and CABI.

Bustamante, P.G. & Ferreira, F.R. 2011. Accessibility and exchange of plant germplasm by EMBRAPA. *Crop Breeding and Applied Biotechnology*, S1: 95–98.

Engelmann, F., ed. 1999. *Management of field and* in vitro *germplasm collections*. Proceedings of a Consultation Meeting, 15–20 January 1996. Cali, Colombia, CIAT, and Rome, IPGRI.

FAO. 1995. Collecting woody perennials. *In* L. Guarino, V.R. Rao & R. Reid, eds. *Collecting plant genetic diversity. Technical guidelines*, pp. 485–511. Wallingford, UK, CABI.

Ferreira, F.R. & Nehra, N. 2011. *Forestry germplasm exchange and quarantine in Brazil. In* Society of American Foresters, National Convention, Honolulu, Hawaii, USA, 2-6 November 2011 (available at: http://www.eforester.org/natcon11/program/2011conventiononsitebook.pdf).

Frison, E.A. & Taher, M.M., eds. 1991. *FAO/IBPGR technical guidelines for the safe movement of citrus germplasm*. Rome, FAO and IBPGR.

Guarino, L., Rao R., V. & Reid, R., eds. 1995. *Collecting plant genetic diversity*. *Technical guidelines*, Wallingford, UK, CAB International.

Marshall, D.R. & Brown, A.H.D. 1975. Optimum sampling strategies in genetic resources conservation. *In* O.H. Frankel & J.G. Hawkes, eds. *Crop genetic resources for today and tomorrow*, pp. 3–80. Cambridge, UK, Cambridge University Press.

Reed, B.M., Engelmann, F., Dulloo, M.E. & Engels, J.M.M. 2004. *Technical guidelines for the management of field and* in vitro *germplasm collections*. Handbooks for Genebanks No. 7. Rome, IPGRI.

Said Saad, M. & Rao, V.R., eds. 2001. *Establishment and management of field genebank training manual*. Serdang, Malaysia, IPGRI-APO.

SGRP-CGIAR. Crop Genebank Knowledge Base. Field genebanks (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english).

Veiga, R., Ares, I., Condon, F. & Ferreira, F.R. 2010. *Intercambio seguro de recursos fitogenéticos*. *In* Estrategia en los recursos fitogenéticos para los países del Cono Sur/IICA. pp. 75–83. Montevideo, PROCISUR, IICA.

Walter, B.M. & Cavalcanti, T.B. 2005. *Fundamentos para a coleta de germoplasma vegetal*. D.F. Brasil, Embrapa Recursos Genéticos.

5.3 Standards for establishment of field collections

Standards

5.3.1 A sufficient number of plants should be maintained to capture the genetic diversity within the accession and to ensure the safety of the accession.

5.3.2 A field genebank should have a clear map showing the exact location of each accession in the plot.

5.3.3 The appropriate cultivation practices should be followed taking into account micro-environment, planting time, rootstock, watering regime, pest, disease and weed control.

Context

It is difficult to provide specific standards for the establishment of a field genebank collection. It will depend very much on the nature of the species that are intended to be conserved. Species-specific standards will have to be developed depending on the biological characteristics of the species, its phenology, reproductive mechanism and population structure. There are three main considerations that should be taken in to account in establishing a field genebank collection: (a) how many plants per accessions should be maintained; (b) how the plants are laid out within the genebank; and (c) what cultivation practices need to be applied to ensure optimal growing conditions of the accessions in the collections.

Technical aspects

The decision for determining how many plants per accession should be planted in a field genebank hinges on the balance of the need to maintain the genetic diversity of accessions, space considerations, need for characterization and economic conditions of the field genebank. It will be different for annual and perennial plants, and whether species are seed or vegetatively propagated. In the case of seed propagated species, the sample size needs to be sufficiently large to capture the genetic diversity contained in the accession that has been collected. It is worth noting here that during collecting non-orthodox seed material, a proper sampling design that prioritizes plants for collection has to be made as it will be difficult to harbour a lot of 'within accession genetic diversity' in a field genebank collection. For vegetatively propagated species, only a small number of plants is necessary to represent the genetic diversity within the accession and to ensure the security of the accession. However, more plants may be needed in some cases, when the within-population diversity is greater than between-population diversity. Sample size can also depend on the purpose for establishing the collection, i.e. evaluation and/or distribution, which may determine different number of individuals per accession as compared to conservation purposes.

In establishing a field genebank collection, it is very important to know what accessions are being planted where. A proper planned layout and well prepared field plan will enhance efficiency of space use and management of the collection. The location of individual accessions should be clearly defined. In this respect, plot layout, design, electronic and print maps, as well as barcodes and field labels should be incorporated at the field genebank establishment phase. Considerations should be given to placing accessions in the most appropriate micro-environment in the genebank. Some plants require special environmental conditions and may need to be housed in greenhouses to have a greater environmental control (e.g. to avoid heat or cold) or require shading by other plants.

The growth habits and the adult size of the plants as well as irrigation structures and the ease of maintenance need to be considered when calculating the size of the plots. For perennial species, appropriate spacing of plants within the plot allows for proper growth of the individual plant, e.g. a tree, and avoids admixture of those crops that develop tubers on long underground stolons. In addition physical barriers should be implemented between plots to avoid admixture (gene flow), for instance by separating the plots with different species that do not cross pollinate. It helps avoid competition that may result in weak plants or could favour rapid spread of disease or insect pests. Invasive clones may require planting in cans, pots or boxes to reduce mixing or competition with less vigorous accessions. Accessions with easily distinguishable morphologies may be planted in adjacent plots when creeping, spreading or shedding of bulbils or seeds to the adjacent plot is a problem. For out-crossing species, sufficient isolation distance between plots of different accessions or measures, such as isolation cages, are required to maintain the genetic integrity of any seeds collected for distribution.

It should be emphasized that the layout and field plan are not fixed in time, and will change according to planting schedules. In the case of annuals, rotation is essential and this requires proper scheduling and additional space. It is also important to design layout so as to ensure that there are no pesticide drifts to the immediate environment.

Correctly and clearly written labels with two water resistant indelible tags are extremely important in field collections. The tags should contain information on: date, common name and field collection number. If possible, computer-produced labels should be used because they reduce transcription errors in names and numbers. Field maps (as hard copy and in digital form) are essential documents for field genebanks and provide a backup to field labels that are easily lost or destroyed. They should be developed before planting and kept updated regularly.

The establishment of field genebank collection requires that the appropriate cultivation practices, specific to the species, be adopted to ensure successful establishment of plants in the field genebank. Planting material needs to be selected carefully. Selecting only strong plants to retain in the field genebank could reduce genetic variation. The quality of initial planting material from a phytosanitary perspective is extremely important when planting new fields or replanting empty plots or when rejuvenating entire collections as long as no genetic selection would be undertaken. Only healthy material and vigorous parts of the plant should be used. Simple sanitary care, like using clean disinfected tools in the preparation of planting materials should be observed. The possibility of indexing for non-apparent diseases such as viruses and graft-transmitted pathogens (i.e. viroids, phytoplasmas and non-identified organisms) prior to establishment should be considered where possible.

Plants should be planted at the right time. Where recommendations on planting time for different species from different areas have been developed these should be followed. These should take into account optimal conditions for plant establishment, which could include temperature, moisture levels, soil type and rootstock etc. For plants propagated by grafting, one must be careful to get the rootstocks in a standardized way to do the grafting of all samples at the right time. Specific types of species are grafted on a rootstock of the same species, or a closely related one with proven good

compatibility. In those cases, the same rootstock should be used for all the accessions of that species. The rootstocks must be selected for their adaptation to soil characteristics and minimum influence on the behaviour of the grafted material. Trees should be planted on their own roots, not grafted, except if the use of rootstocks are needed to prevent disease or if the graft is the normal form of cultivation of a species.

Crops that require cross-pollination should be planted in groups by bloom date. In dioecious species, a suitable amount of male/female plants should be planted. For self incompatible species asexually propagated, the curator has to know which self-incompatibility (SI) system is presented by the species and the allelic combination in order to have a good field collection and to guarantee fruit or seeds formation. It is also important to observe the land treatment (agro-technical measures) during establishment of field collections.

Some species require additional support by planting shade trees in an appropriate design (e.g. coffee), which need to be chosen according to the local conditions and the requirements of the species. Some species grow as lianas (e.g. vanilla, many beans, cucurbits and others) and need trees, wooden sticks, wires or other installations for proper growth. It may be necessary to install very special beds for special species (mainly those from arid climates), e.g. "table beds" and shelters to keep away precipitation in certain periods of the year. The same may be true for special shading periods, irrigation or flooding times or covers to protect against frost etc. Some fruit tree species need regular pruning to express their typical appearance and remain healthy. For tree crops, another practice that should be strongly encouraged is the use of dwarfing rootstocks.

Contingencies

Some genotypes may not respond well to general propagation methods established for particular species types and research should be carried out to develop new methodologies. In the case of plants propagated with rootstock in a planting site requiring the use of a closely related species as rootstock, an interstock should be used.

It is important to consider maintaining the collection duplicated at another location (see Standards for security and safety duplication). Some genotypes, e.g. those found in forest understorey or may be disease susceptible, may not adapt well to conditions of full sun in the field and thus need to be provided with adequate shelter. This is exacerbated by resource constraints, causing a dual role for field genebanks (conservation plus crop improvement) which can lead to conflicts, e.g., in genebank layout, management, and duplication of accession. When maintaining field duplication is difficult, a possible option is to establish duplicates in the form of *in vitro* cultures.

SELECTED REFERENCES

Reed, B.M., Engelmann, F., Dulloo, M.E. & Engels, J.M.M. 2004. *Technical guidelines for the management of field and* in vitro *germplasm collections*. Handbooks for Genebanks No. 7. Rome, IPGRI.

Sebbenn, A.M. 2002. Número de árvores matrizes e conceito genéticos na coleta de sementes para reflorestamentos com espécies nativas. *Revista do Instituto Florestal de São Paulo,* V.14(2): 115–132.

SGRP-CGIAR. Crop Genebank Knowledge Base. Field genebanks (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english).

5.4 Standards for field management

Standards

5.4.1 Plants and soil should be regularly monitored for pests and diseases.

5.4.2 Appropriate cultivation practices such as fertilization, irrigation, pruning, trellising, rootstock and weeding should be performed to ensure satisfactory plant growth.

5.4.3 The 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.

Context

Field management refers to the day-to-day curating of the field collections to ensure that plant accessions are in good health, are easily accessible and available for use. This involves many different activities including pest and disease control, proper nutrition of the plants, watering, weeding, pruning and monitoring of accessions to ensure genetic integrity of the collections.

Technical aspects

Germplasm losses due to poor health can be a major cause of genetic erosion in field genebanks. Maintaining healthy plant accessions in germplasm collections is a major challenge, especially when accessions are collected from a wide area of distribution where different pest and diseases exist. Accessions within collections can also be a source/focus of pest and disease spread if not properly managed. Therefore, it is important that strict control of plant introductions into the field genebank be exercised. In addition, current and historical levels of both insect and diseases populations must be considered. Careful inspections and recording are very important in all pest management operations. The timing of disease control is also of paramount importance since after the plant material is infected the damage is often irreversible. Modelling of climatic scenarios and diseases could also assist in the on control of new emerging pests and diseases.

Insect pests and diseases may include a very wide range of organisms depending on the target collections. Some of the most commonly associated plant germplasm pests include insects, mites, fungi, bacteria, nematodes, viruses, viroids, spiroplasma, phytoplasma, slug, snails as well as weeds. Vegetatively propagated plants may be virus-infected, leading to impairment of vigour, hardiness, and graft incompatibility, among others. During quarantine or maintenance, insect pests and diseases may be detected through a number of techniques including visual examination, isolation by agar plate method/streak plate method, moist chamber incubation, grafting, bioassays, electron microscope examination and plant diagnostic kits. The latter may include enzyme-linked immunosorbent assay (ELISA), which is easy to use, and already available for diseases of root crops (cassava, potato, beet), fruits (banana, pome, stone, and soft fruits) and vegetables. Major plant fungal and bacterial diseases must be controlled by prophylaxis, or prevention. DNA-based diagnostic kits are also extremely efficient in detecting diseases through PCR analysis of specific genes of pathogens. It is advisable to have staff trained in agronomy, horticulture, micropropagation, and pathology performing disease assessments.

Correct identification, at the time of delivery, of accessions susceptible to insect pests and diseases is desirable. It is important that field genebanks have a system in place for the identification of all associated pests and diseases for the range of crops they hold in their collection. This is especially true for those crops for which quarantined high risk pathogens have been described. Genebanks should also have procedures in place for the application of relevant diagnostic methodologies that give rigorous assurance on pest and disease status, as directed by local, regional and country requirements. In cases where a genebank does not have this capacity, these tasks should be outsourced to specialized institutions for quarantining incoming plants.

Genebank staff need to apply management practices that reduce the risks of spreading diseases within the collection. It is necessary to ensure that tools and implements, soil and footwear are properly sanitized. Integrated pest management (IPM) is a recommended approach for pest control, where possible. This program uses biological control where possible, supplementing it with pesticides and mechanical control. It can be very important to test clonal material for viruses and other graft-transmitted pathogens, as there has been much improvement in detection technology over the past decade. If unique plants are found to be infected, they should be cleaned by thermotherapy and/or tissue culture. To avoid costly therapy, it is always recommended to find similar material from "clean" or less infected sources.

The field genebank management staff must be proactive to meet the individual needs of diverse germplasm. After planting the plot, staff need to aid the growth of plants only by supplying favourable conditions for their development. Watering plants regularly during the dry season is far more important than fertilizing them. The irrigation system should be appropriate for the type of plant and the ecological conditions where the field collection is established. Fertilization of the field collection is complicated by the fact that many different types of plants are grown together. Each type of plant has special nutrition requirements due to genetic differences, size, or age. Compound mixtures can be used with low amount per plant and proper care to assure distribution. Small amounts applied at intervals may be more effective than the same total amount applied at intervals of several months. Pruning is necessary in most plants to keep their size within acceptable parameters within the plantation and in the case of trees to shape their canopy. Sometimes, only a light thinning should be made in order for the branches to have space to develop properly without excessive competition for light. This shaping and thinning operation should be entrusted to an experienced person. Due to the importance of a germplasm collection, labour must be of high quality and field maintenance should be done by trained personnel.

Competition with weeds is a much more serious problem for young plants than for old ones because of their shallower rooting system. Weed control is important for a rapid and vigorous plant growth. Weeds can be controlled by mechanic ways or using chemicals (herbicides). Herbicides can be used to reduce to a minimum the necessity of hand labour and mechanical cultivation. The type of weed control should be the recommended for each species.

In some accessions, other protection practices are needed such as frost and/or hail protection or against insect disease vectors using screenhouses. Fruit removal is also an important management practice for disease control, to avoid competition with the next year crop and to reduce stress on the plant.

In order to ensure the genetic identity of each accession, any contamination among accessions, geneflow from neighbouring plants and inter-growth of accessions should be avoided. Accessions in field collections may produce flowers and subsequent seeds that drop and could grow in the plot area. These seeds may not breed true due to heterozygosity, or may be cross-pollinated. Such involuntary seeding needs to be prohibited or rogued out. Monitoring and periodic checks should be made to ensure that each accession is properly identified and mapped in the field. Labelling is extremely important and needs to be constantly verified on site and compared to plot plans of the field genebank. Labels should be clear, concise and be as weather-proof as possible. The use of barcodes or other computer-generated labels are encouraged to reduce transcription errors. Identity of each accession should be periodically checked using morphological and molecular markers when possible (see Standards for characterization).

The maintenance practices are usually crop specific and may vary according to the intended use of the collection (conservation, evaluation, distribution). All germplasm accessions should be monitored, however frequency depends on whether the plant is herbaceous (with higher frequency of monitoring) vs. woody (less frequently monitored). All germplasm should be monitored for new animal, insect and disease pests that may be introduced into the germplasm collections. All germplasm must be monitored for vandalism as well (see Standards for security).

Contingencies

The lack of expertise in genebanks in dealing with pest and diseases can be a major limiting factor for maintaining healthy plants in the collection, for which skilled plant pathologists may be required. Genebanks should have contingency plans in place to deal with outbreaks of diseases. They should be in contact with specialized plant pathology services such as national plant pathology authorities, university laboratories or commercial laboratories, all of which may provide the services they require.

Another good practice is to rotate planting sites (where possible, especially for annually propagated species and perennials highly susceptible to soil sickness) so as to reduce the perpetuation of any soil-borne pests and diseases. Another option is to disinfect the soil. In some cases, plants can be grown in a nursery where phytosanitary conditions can be easier managed, and then be planted out in the field when plants have been acclimated.

Some accessions may be very valuable and vulnerable to pathogens. For such cases, it is important to keep them in screen houses and to keep duplicates *in vitro* or in cryopreservation as a complementary conservation backup.

Hand weeding might be required where plants might be injured by herbicide applications. Utilizing sites that do not favour pests and disease development for regeneration purposes is advisable.

SELECTED REFERENCES

Mathur, S.B. & Kongsdal, O. 2003. *Common laboratory seed health testing methods for detecting fungi.* Bassersdorf, Switzerland.

Navarro, L. 1988. Application of shoot-tip grafting *in vitro* to woody species. *Acta Horticulturae*, 227: 43–55.

Navarro, L., Civerolo, E.L., Juárez J. & Garnsey, S.M. 1991. Improving therapy methods for citrus germplasm exchange. *In* R.H. Brlansky, R.F., Lee & L.W. Timmer, eds. *Proceedings of XI Conference of the International Organization of Citrus Virologists*, pp. 400–408. Riverside, Florida, USA.

Reed, B.M., Engelmann, F., Dulloo, M.E. & Engels, J.M.M. 2004. *Technical guidelines for the management of field and* in vitro *germplasm collections*. Handbooks for Genebanks No. 7. Rome, IPGRI.

Roistacher, C.N., Navarro, L. & Murashige, T. 1976. Recovery of citrus selections free of several viruses, exocortis viroid, and Spiroplasma citri by shoot-tip grafting *in vitro*. *Proceedings of VII Conference of the International Organization of Citrus Virologists*, pp.186–194. Riverside, Florida, USA.

SGRP-CGIAR. Crop Genebank Knowledge Base. Field genebanks (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english).

Sheppard, J.W. & Cockerell, V. 1996. *ISTA PDC handbook of method validation for the detection of seedborne pathogens*. Basserdorf, Switzerland, ISTA.

Sutherland, J.R., Diekmann, M. & Berjak, P. 2002. *Forest tree seed health.* IPGRI Technical Bulletin N° 6. Rome, IPGRI.

5.5 Standards for regeneration and propagation

Standards

5.5.1 Each accession in the field collection should be regenerated when the vigour and/or plant numbers have declined to critical levels in order to bring them to original levels and ensure the diversity and genetic integrity is maintained.

5.5.2 True-to-type healthy plant material should be used for propagation.

5.5.3 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.

Context

In the context of field collections, the terms regeneration and propagation refer to the re-establishment of germplasm samples that are genetically similar to the original collection when vigour or plant numbers are low (Dulloo *et al.,* 2008). Standards for regeneration and propagation procedures would need to be species specific. When available, protocols or guidelines for particular species should be used. Regeneration and propagation should aim at ensuring that there is no loss of any plants within the collection. However, it is inevitable that the loss of any single individual would entail genetic erosion within the accession because there are normally only a few plants for each accession (see Standards for establishment of field collections: sample size). Regeneration and propagation are costly and should be carefully planned. They may require changing sites for security or to avoid diseases, pests and soil sickness processes.

Technical aspects

Regeneration and propagation may be necessary for a variety of reasons depending on the plant type, threats and distribution needs. A plant may decline in vegetative vigour or even die from many different causes, due to climatic, edaphic and/or biotic factors. For maximum efficiency in a field collection plot, it is essential that every dead plant be replaced. This is especially important since the number of individuals per accession is generally low in field collections (see Standards for establishment of field collections).

The method of propagation of the target species is an important consideration. Some species can be propagated by seeds while other species are propagated vegetatively. In principle, seeds should not be used for propagation in a field collection even if the species can reproduce by seeds unless the population size is represented by a sufficiently large number of individuals. As the objective of regeneration is to maintain the genetic integrity of the accession and, given that there is only a limited number of plants per accession, propagation through seeds can lead to significant genetic drift in the accession. In addition, in cross-pollinated species, hybridization between accessions may effectively reduce the genetic variance between accessions and change the integrity of individual accessions. Whenever possible, plants should be propagated vegetatively in which case each offspring is an exact replica of the parent and hence genetic integrity of the accession is maintained.

The time at which regeneration should be carried out is another important factor, which often depends on climate and planting season of the crop. FAO has published a series of crop calendars for Latin America and Africa (FAO, 2004, 2012), which can be a useful guide in determining the appropriate time for planting, and thus for regeneration. The FAO crop calendars provide information for more than 130 crops, located in 283 agro-ecological zones of 44 countries. Again, the timing will be species- and possibly site-specific. A good indication of when to initiate propagation is provided when propagules start to sprout or mother plants start to die continuously. Another consideration will be whether or not the collection is to be ratooned, i.e. suckers are allowed to develop to produce the next crop, as is the case for aroids (Jackson, 2008).

Propagation should be done using true-to-type and healthy plant material. If available, the new plant has to be regenerated using propagation material stored in special facilities (greenhouses, *in vitro*, or freezer) to ensure its health. Available protocols or guidelines for particular species should be used. Regeneration of accessions of out-crossing species should be made in isolation using special facilities and protection for weeds, pests and diseases.

It is important that all information relating to the regeneration of the accession be properly documented and included in the genebank documentation system. This should include *inter alia* information about the accession number and the plant sequence number within each accession, the site where regeneration is carried out, the type of propagation and materials used (cuttings, tuber, corms, bulbs), planting date, survival rate of the propagated materials, the protocol for seed dormancy-breaking, management practices employed, method of planting, field conditions, number of plants established and harvest dates).

Contingencies

Climatic factors may be more harmful to young plants than to older ones. Because a few plants are likely to be lost during the first year due to various causes, it is a wise precaution at planting to keep some plants for use as replacement if needed. This assures to have plants of the same type and age as the original for replacing lost individuals.

Field collections are extremely vulnerable to climatic and other environmental disturbances and it is very important for field genebanks to have a contingency plan for urgent regeneration of the collection. A safety backup may be maintained *in vitro* or cryopreserved as a complementary measure. Contingencies may also occur with wild relatives of crops and native species for which regeneration protocols are yet to be developed. These may often require different treatments when compared with cultivated relatives.

SELECTED REFERENCES

Costa, N., Plata, M.I. & Anderson, C. 2004. Plantas cítricas libres de enfermedades. *In* V. Echenique, C. Rubistein & L. Mroginski, eds. *Biotecnología y Mejoramiento vegetal*, pp. 317–318. Argentina, INTA.

Dulloo, M.E., Thormann, I., Jorge, A.M. & Hanson J., eds. 2008. *Crop specific regeneration guidelines*. [CD-ROM], Rome, SGRP–CGIAR.

FAO. 2004. *Calendario de cultivos. América Latina y el Caribe*. Estudio FAO producción y protección vegetal No. 186. Rome.

FAO. 2012. *Crop calendars* (available at: http://www.fao.org/agriculture/seed/cropcalendar/welcome.do).

ICRISAT (International Crops Research Institute for the Semi-Arid-Tropics). Germplasm regeneration (available at: http://www.icrisat.org/what-we-do/genebank/genebank-manual/germplasm-regeneration-9.pdf).

Jackson, G.V.H. 2008. Regeneration guidelines: major aroids. *In* M.E. Dulloo, I. Thormann, A.M. Jorge & J. Hanson eds. *Crop specific regeneration guidelines*. [CD-ROM], Rome, SGRP-CGIAR.

Plata, M.I. & Anderson, C.M. 2008. In vitro *blueberry* (Vaccinium *spp.*) *germplasm management in Argentina*. 9th International Vaccinium Symposium, ISHS, Corvallis, Oregon, USA.

Sackville Hamilton, N.R. & Chorlton, K.H. 1997. *Regeneration of accessions in seed collections: a decision guide*. J. Engels, ed. Handbooks for Genebanks No. 5. Rome, IPGRI.

SGRP-CGIAR. Crop Genebank Knowledge Base. Field genebanks (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english).

5.6 Standards for characterization

Standards

5.6.1 All accessions should be characterized.

5.6.2 For each accession, a representative number of plants should be used for characterization.

5.6.3 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.

5.6.4 Characterization is based on recording formats as provided in internationally used descriptors.

Context

Characterization is the description of plant germplasm, and a tool for the description and fingerprinting of the accessions, confirmation of their trueness to type, and identification of duplicates in a collection. It determines the expression of highly heritable characters ranging from morphological, physiological or agronomical features, including agrobotanic traits such as plant height, leaf morphology, flower colour, seed traits, phenology, and overwintering ability for perennials. These are essential information for curators to distinguish among samples in the collection.

For field collections, characterization can be carried out at any stage of the conservation process. However, it is essential that the accessions being conserved are known and described to the maximum extent possible to assure their maximum use for customers and stakeholders. Therefore, characterization should be carried out as soon as possible to add value to the collection. The time will vary from species to species depending on their life cycle. The use of a minimum set of phenotypic, physiological and morphological descriptors and information on the breeding system, selected from internationally used descriptor lists (e.g. those published by Bioversity International, the International Union for the Protection of New Varieties of Plants [UPOV] and the USDA's National Plant Germplasm System [USDA-ARS NPGS]) increases the usefulness and cross-referencing of the characterization data.

With the advances in biotechnology, molecular marker technologies and genomics are increasingly used for characterization (De Vicente *et al.*, 2004). Characterization will allow true-to-type identification, detecting gene flow and setting reference profiles, identifying mislabelling and duplications, detecting diversity within and among accessions and coefficient of parentage. Measures, such as splitting samples, may be necessary for ensuring the preservation of rare alleles or for improving access to defined alleles. Documentation of observations and measures taken is extremely important.

Technical aspects

In contrast to seed collections, phenotypic characterization of field collections is easier to perform, given that the plants are in the field and the scoring of the relevant traits for characterization can be done at the appropriate time and repeated over the years.

Some relevant characterization data can be obtained when collecting in the field, so the time for collecting expeditions should be carefully planned whenever possible. Accessions could then be characterized side by side in the field when collected. The historical and cultural information obtained from farmers, botanists, horticulturalists, or native people during collecting expeditions is usually valuable. Local knowledge about the origin of an accession and disease and insect resistance can decrease characterization costs and limit duplication.

Descriptors for crops are defined by crop experts and/or curators in consultation with crop experts and genebank managers for relevancy to increase utilization of collections. A wide range of crop descriptor lists has been developed (for example by Bioversity International, UPOV, the International Organisation for Vine and Wine (OIV) and the USDA-ARS NPGS), as well as minimum sets of key descriptors for utilization have been established for several crops. Data recording needs to be conducted by trained staff using calibrated and standardized measuring formats as indicated in the descriptor lists. The data need to be validated by curators and documentation officers before being uploaded into the genebank database and made publicly available to encourage the use of the collection. It is also recognized that reference accessions planted in the same field are needed to score the traits. Reference collections (herbarium specimens, high quality voucher images) play an essential role for true-to-type identification.

The number of plants characterized within an accession should be a representative sample, which in turn depends on its diversity. In general, there should be a minimum of 3 plants for diverse accessions, whereas for clonal plants 1-2 are sufficient[1], in order to have statistically sound measurements. In species prone to mutation (e.g. citrus), annual characterizations for key characters should be done for true-to-type verification.

With the advances in biotechnology, molecular marker technologies and genomics are increasingly used for characterization (De Vicente *et al.*, 2004), in combination with phenotypic because they have advantages on ensuring the identity of clonal plants, identifying mislabelling and duplications, detecting genetic diversity and parentages within and among accessions. Genotypic data obtained from characterizing germplasm using molecular techniques have the advantage over phenotypic data in that variations detected through the former are largely devoid of environmental influences (Bretting and Widrlechner, 1995). The technologies develop fast and costs are also decreasing quickly, allowing a more extensive use in the field collections, and should be used when resources do allow it. However, the dearth of adequately skilled personnel and the lack of resources for the relatively high set-up costs continue to prevent the widespread adoption of molecular markers as a method of choice for germplasm characterization especially in developing countries. There are many markers and techniques available (e.g. simple sequence repeats [SSR], expressed sequence tags - simple sequence repeats [EST-SSR], amplified fragment length polymorphisms [AFLP]) but, for characterization purposes, only well-established, repeatable markers such as SSR should be used.

For many crops, a wide range of marker primers suitable for their use in characterization has been developed; also, minimum sets of key markers have been established. In order to ensure that the results of different analysis batches are comparable, some genebank accessions should be included as reference on each batch. The inclusion of reference accessions in molecular characterizations also plays an essential role for comparison among different genebanks.

1 http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=47&Itemid=205&lang=english

One of the most advanced techniques employed in the improvement of tree species is genome-wide selection (GWS) (Grattapaglia and Resende 2011; Fonseca *et al.,* 2010). GWS requires the use of molecular markers that allow for wide coverage of the genome and high density genotyping. Although this technique is applied for improvement, the information generated can be used to characterize and conserve new accessions or superior genotypes.

Contingencies

Reliability of data might vary among data collectors and depends on training and experience. Therefore, trained and experienced technical staff in the field of plant genetic resources should be available during the entire growth cycle to record and document characterization data. Access to expertise in taxonomy, seed biology, plant pathology and molecular characterization (in-house or from collaborating institutes), during the process of characterization is desirable. For those crops for which there are no internationally used descriptor lists, it should be necessary to develop them while using available descriptor lists for related crops or species as references.

SELECTED REFERENCES

Alercia, A., Diulgheroff, S. & Mackay, M. 2012. FAO/Bioversity *Multi-Crop Passport Descriptors* (MCPD V.2). Rome, FAO and Bioversity International (available at: http://www.bioversityinternational.org/uploads/tx_news/1526.pdf).

Bioversity International. 2007. *Developing crop descriptor lists. Guidelines for developers.* Technical Bulletin No. 13. Rome.

Bioversity International. 2007. List of published crop descriptors (available at: http://www.bioversity international.org/index.php?id=168).

Bioversity International. 2013. Descriptor lists and derived standards (available at: http://www.bioversityinternational.org/index.php?id=168).

Bretting, P.K. & Widrlechner, M.P. 1995. Genetic markers and plant genetic resource management. *Plant Breeding Reviews*, 13:11–86.

De Vicente, M.C., Metz, T. & Alercia, A. 2004. *Descriptors for genetic markers technologies*. Rome, IPGRI.

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. Handbooks for Genebanks No. 6. Rome, IPGRI.

Fang, D.Q., Roose, M.L., Krueger, R.R. & Federici, C.T. 1997. Fingerprinting trifoliate orange germplasm accessions with isozymes, RFLPs, and inter-simple sequence repeat markers. *Theor. Appl. Genet.*, 95:211–219.

Fonseca, S.M., Resende, M.D.V., Alfenas, A.C., Guimarães, L.M.S., Assis, T.F. & Grattapaglia, D. 2010. *Manual prático de melhoramento genético do eucalipto*. UFV, Viçosa, MG.

Grattapaglia, D. & Resende, M.D.V. 2011. Genomic selection in forest tree breeding. *Tree Genetics & Genomes*, 7: 241.

Lateur, M., Maggioni, L. & Lipman, E. 2010. *Report of a Working Group on Malus/Pyrus*. Third Meeting, 25-27 October 2006, Tbilisi, Georgia. Rome, Bioversity International.

Maggioni, L., Lateur, M., Balsemin, E. & Lipman, E. 2011. *Report of a Working Group on Prunus*. Eighth Meeting, 7-9 September 2010, Forlì, Italy. Rome, Bioversity International.

OIV (International Organisation of Vine and Wine). 2009. *OIV descriptor list for grape varieties and* Vitis *species*. 2nd ed. Paris.

SGRP-CGIAR. Crop Genebank Knowledge Base (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=97&Itemid=203&lang=english).

UPOV(International Union for the Protection of New Varieties of Plants). Descriptor lists (available at: http://www.upov.int/test_guidelines/en/list.jsp).

USDA, ARS, National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). [Online Database] Evaluation/characterization. Data Queries. National Germplasm Resources Laboratory, Beltsville, Maryland, USA (available at: http://www.ars-grin.gov/cgi-bin/npgs/html/croplist.pl).

5.7 Standards for evaluation

Standards

5.7.1 Evaluation data on field genebank accessions should be obtained for traits of interest and in accordance with internationally used descriptor lists where available.

5.7.2 The methods/protocols, formats and measurements for evaluation should be properly documented with citations. Data storage standards should be used to guide data collection.

5.7.3 Evaluation trials should be replicated (in time and location) as appropriate and based on a sound statistical design.

Context

Evaluation is the recording of those characteristics whose expression is often influenced by environmental factors. It involves the methodical collection of data on agronomic and quality traits through appropriately designed experimental trials. Evaluation data frequently includes insect pest and disease resistance and quality evaluations (e.g. oil, protein or sugar content or density), production (wood, grain, fruits, seeds, leaf, other) and abiotic traits (drought/cold tolerance and others). These data sets are all highly desired by users to incorporate useful traits into breeding programs and help to improve utilization of the collections. The traits for which the germplasm accessions are assayed are defined in advance by crop experts in collaboration with gene bank curators. Reliable evaluation data that are easily retrievable by plant breeders and researchers facilitate greatly the use of plant germplasm accessions. Germplasm may be systematically evaluated using a network approach, at either an international level or national level.

Obtaining evaluation data by genebanks is time consuming and frequently more expensive than obtaining characterization data. Thus, evaluation should be prioritized for those accessions that have outstanding features and collaboration with breeders and other specialists (virologists, entomologists, mycologists) is recommended in this endeavour. Curators should make all possible efforts to obtain at least some minimum records of evaluation data. Possible sources of evaluation data may be obtained from users to whom germplasm materials have been distributed previously. The genebank should solicit the user to share the evaluation data and practical arrangements in this regard should be worked out between the genebank and the recipients/users of the material. Such information could address resistances to biotic and abiotic stresses, growth and development features of the germplasm, quality characteristics of yield, etc. Adding this type of information to the genebank database allows more focused identification of germplasm to meet prospective client needs. Such data should be included in the genebank's documentation system after appropriate verification and validation.

Technical aspects

A wide range of crop descriptor lists have been developed, for example, by Bioversity International and UPOV. Furthermore, there are evaluation descriptor lists developed by regional and national organizations such as USDA-ARS NPGS.

Data collection should be conducted by trained staff using as much as possible calibrated and standardized measuring formats with sufficiently identified check accessions and published crop descriptor lists. The results of greenhouse, laboratory or field evaluations, following standardized protocols and experimental procedures are usually presented as either discrete values (e.g. scores for severity of disease symptoms; counting) or continuous values (based on measuring). The data need to be validated by curators and documentation officers before being uploaded into the genebank database and made publicly available.

Many agronomic traits required by breeders are too genetically complex to be screened for in preliminary evaluations of germplasm accessions. Data on agronomic traits are usually obtained during the evaluation of germplasm in a breeding program, and many of these traits result from strong genotype by environment

(G × E) interactions and hence are site-specific. It is essential to use replications for the evaluation of desired traits in different environments and to clearly define and identify check accessions to be used over time. Check accessions facilitate comparisons across years of data collected.

With the advances in biotechnology, molecular marker technologies and genomics are increasingly used for evaluation as well (De Vicente *et al.*, 2004) (see standards on characterization). The most commonly used molecular markers in germplasm characterization and evaluation include AFLPs, SSRs, and single nucleotide polymorphisms (SNP). They have largely replaced the older marker types, restriction fragment length polymorphism (RFLP) and random amplified polymorphic DNA (RAPD) on account of their relative genomic abundance and the high reproducibility of data. In addition, advances in next generation sequencing and the accompanying reduction in costs have resulted in the increasing use of sequencing-based assays such as the sequencing of coding and non-coding regions and genotyping-by-sequencing (GBS) in germplasm evaluation. Molecular markers vary in the way they detect genetic differences, in the type of data they generate, in the taxonomic levels at which they can be most appropriately applied, and in their technical and financial requirements (Lidder and Sonnino 2011). Where marker assisted selection (MAS), i.e. the selection for the presence or absence of traits in breeding materials at the molecular level, is feasible, it can also be applied in the evaluation of germplasm for traits of interest. The dearth of adequately skilled personnel and the lack of resources for the relatively high set-up costs continue to prevent the widespread adoption of molecular markers as a method of choice for germplasm evaluation especially in developing countries.

Contingencies

Reliability of data might vary among data collectors if they are not well trained and experienced and when data collection procedures are not harmonized. Therefore, trained technical staff in the field of plant genetic resources should be available to collect and document evaluation data. The participation of multi-disciplinary teams with expertise in plant pathology, entomology, and environmental (abiotic) stress tolerance, both in-house and from collaborating institutes, during the process of evaluation is highly desirable.

The evaluation of plant germplasm is very labour-intensive and requires adequate and continuous levels of sustainable funding to allow for the assemblage

of reliable high quality data. In situations where carrying out the full evaluation of all accessions, which though desirable may not be economically feasible, the selection of genetically diverse accessions (based for instance on previously delineated sub-sets of germplasm collections) is recommended as a starting point.

Variations in the incidences of pests and diseases, the severity of abiotic stresses and the fluctuations in environmental and climatic factors in the field impact on the accuracy of data and should be mitigated through reasonably replicated, multi-locational, multi-season and multi-year evaluations. Also, the laboratory assays for the measurements of some traits like oil or protein contents, starch quality, nutritional factors, require specialized equipment and skilled staff that are not always available or could be costly. This again underscores the need for the participation of multi-disciplinary teams from several organizational units or institutions as the case may be. The sanitary status (viruses) of the accession may have incidence in the evaluation as well as in morphological descriptions.

Using the evaluation data generated by others could pose significant practical challenges. For instance, the data may be in different formats, and if published already may involve copy right and intellectual property rights issues. In order to facilitate the use of externally sourced data, it is important to standardize data collection, analysis, reporting and inputting formats.

It should be noted that many characters may appropriately be evaluated within a field-planted genebank itself. However, stresses that impose risks to the collection, and may result in accession losses if uncontrolled, should be evaluated in separate, specially designed trials. Serious insect pests and diseases or major soil problems are examples. The field collection often is not an appropriate place to evaluate yield or quality because of inappropriate plot design or the need to leave plants in the ground well beyond the normal harvest period.

SELECTED REFERENCES

Ayad, W.G., Hodgkin, T., Jaradat, A. & Rao, V.R. 1997. *Molecular genetic techniques for plant genetic resources*. Report on an IPGRI workshop, 9–11 October 1995, Rome, Italy. Rome, IPGRI.

De Vicente, M.C. & Fulton, T. 2004. *Using molecular marker technology in studies on plant genetic diversity*. Rome, IPGRI, and Ithaca, New York, USA, Institute for Genetic Diversity.

Karp, A., Kresovich, S., Bhat, K.V., Ayad, W.G. & Hodgkin, T. 1997. *Molecular tools in plant genetic resources conservation: a guide to the technologies*. IPGRI Technical Bulletin No. 2. Rome, IPGRI.

Lidder, P. & Sonnino, A. 2011. *Biotechnologies for the management of genetic resources for food and agriculture*. FAO Commission on Genetic Resources for Food and Agriculture Background Paper No. 52. Rome, FAO.

5.8 Standards for documentation

Standards

5.8.1 Passport data for all accessions should be documented using the FAO/ Bioversity 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.

5.8.2 Field management processes and cultural practices should be recorded and documented.

5.8.3 Data from 5.8.1. and 5.8.2 should be stored and changes updated in an appropriate database system and international data standards adopted.

Context

Comprehensive information about accessions, including regularly updated and detailed field maps as well as information about field management processes is essential for a field genebank to manage and maintain its field collections. Documentation of characterization and evaluation data is particularly important to enhance the use of the respective collection and to help in the identification of distinct accessions.

Technical aspects

All data and information generated throughout the process of acquisition, establishment of the collection, field management, regeneration, characterization, evaluation, and distribution should be recorded. Such data and information ranges from details of the genetic characteristics of individual accessions and populations to distribution networks, clients and user feedback. Types of data to be recorded in a field genebank other than passport data and standard crop descriptors are for example, plant catalogues, voucher images (photos, drawings), planting and harvest dates, and notes on the verification (identity) history.

The FAO/Bioversity List of Multi-crop Passport Descriptors (Alercia *et al.,* 2012) should be used for documenting passport data as they are instrumental for data exchange among different genebanks and countries. Standards for documenting characterization data such as the Bioversity International crop descriptors as well as genetic marker descriptors (De Vicente *et al.,* 2004) should be used. With advances in biotechnology, there is a need to complement phenotypic trait data with molecular data. Efforts should be made to record the molecular data being generated through genomics, proteomics, metabolomics and bioinformatics.

Record keeping about the field management processes including daily interventions, is extremely important for good management of the field collection. Good records of field maps (as hard copy and in digital form) are essential to properly document. Old maps should be retained and dated for reference.

Different cultural practices are required for the proper management of accessions of different types of species and should be carefully documented to guarantee their consistent employment over time and the appropriate treatment of accessions.

A majority of genebanks now have access to computers and the internet. Computer-based systems for storing data and information allow for comprehensive storage of all information associated with the management of field collections. Germplasm information management systems such as GRIN-Global have specifically been developed for universal genebank documentation and information management. The adoption of data standards which today exist for most aspects of genebank data management helps make the information management easier and improves use and exchange of data. Sharing accession information and making it publicly available for potential germplasm users is important to facilitate and support the use of the collection. Ultimately, conservation and usability of conserved germplasm are promoted through good data and information management.

All data should be kept up to date. They should also be duplicated at regular intervals and stored at a remote site to guard against loss from fire, computer failure etc. (see standards for security and safety). It can be useful to have written records of the main passport data and hard copies of the field maps.

Contingencies

Lack, or loss, of documentation, field plans or labels compromises the optimal use of the germplasm or can even lead to its loss, if it impedes proper management and regeneration.

Lack of adequate identification of species does not allow to record all necessary information for proper management of the accession and to identify appropriate cultural practices.

SELECTED REFERENCES

Alercia, A., Diulgheroff, S. & Mackay, M. 2012. FAO/Bioversity *Multi-Crop Passport Descriptors* (MCPD V.2). Rome, FAO and Bioversity International (available at: http://www.bioversityinternational.org/uploads/tx_news/1526.pdf).

De Vicente, M.C., Metz, T. & Alercia, A. 2004. *Descriptors for genetic markers technologies*. Rome, IPGRI.

Fabiani, A., Anderson, C. & Tillería J. 1996. *Desarrollo de una base de datos para la evaluación de germoplasma cítrico. (Abstr.)*. VIII Congreso latinoamericano y VI Nacional de Horticultura. Montevideo, Sociedad Uruguaya de Horticultura

Lipman, E., Jongen, M.W.M, van Hintum, Th.J.L., Gass, T. & Maggioni L., comps. 1997. *Central crop databases: tool for plant genetic resources management*. Rome, IPGRI, and Wageningen, Netherlands, CGN.

Painting, K.A, Perry, M.C, Denning, R.A. & Ayad, W.G. 1993. *Guidebook for genetic resources documentation*. Rome, IPGRI.

Tillería, J. 2001. *Sistema DBGERMO para la Documentación de Bancos Activos de Germoplasma*. Memoria, Reunión Técnica para Latinoamérica y el Caribe del Sistema Mundial de la FAO de Información y Alerta para los Recursos Filogenéticos. pp 85–115. Turrialba, Costa Rica.

Tillería, J. & Anderson, C.M. 2004. *The DBGERMO II desktop system for an easy documentation of germplasm collections*. Proc. ISC. (Abstr.), Agadir, Morocco.

Tillería, J. & Zamuz, J. 2011. *La Herramienta Curatorial DBGERMOWeb para la Documentación de Colecciones Vegetales. Demostración de la aplicación web en tiempo real con colecciones documentadas*. VIII SIRGEALC, Quito.

Tillería, J., Andrade, R. & Zamuz, J. 2011. *Documentación de la colección de chirimoya* (Annona cherimola *Mill*) *del INIAP con la herramienta curatorial DBGERMOWeb*. VIII SIRGEALC, Quito.

Tillería, J., Paniego, N., Zamuz, J. & Luján, M. 2009. *El Sistema DBGERMO Web para la Documentación de Colecciones Vegetales*. VII SIRGEALC, Pucón, Chile.

USDA, ARS, Bioversity International, Global Crop Diversity Trust. GRIN-Global. Germplasm Resource Information Network Database - Version 1 (available at: http://www.grin-global.org/index.php/Main_Page).

5.9 Standards for distribution

Standards

5.9.1 All germplasm should be distributed in compliance with national laws and relevant international treaties and conventions

5.9.2 All samples should be accompanied by all relevant documents required by the donor and the recipient country.

5.9.3 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.

Context

Germplasm distribution is the supply of a representative sample from a genebank accession in response to requests from germplasm users. There is a continuous increase in demand for genetic resources to meet the challenges posed by climate change, by changes in virulence spectra of major insect pests and diseases, by invasive alien species and by other end-user needs. This demand has led to wider recognition of the importance of using germplasm from genebanks, which ultimately determines the germplasm distribution. It is important that distribution of germplasm across borders adheres to international norms and standards relating to phytosanitary regulations and according to provisions of international treaties and conventions on biological diversity and plant genetic resources.

Technical aspects

The two international instruments that govern the access of genetic resources are the ITPGRFA and the CBD. The ITPGRFA facilitates access to PGRFA, and provides for the sharing of benefits arising from their utilization. It has established a multilateral system for PGRFA for a pool of 64 food and forage crops (commonly referred to as Annex 1 crops to the Treaty), which are accompanied SMTA for distribution. SMTA can also be used for non-Annex 1 crops; however, other models are also available. Access and benefit-sharing under CBD is according to its Nagoya Protocol. Both the ITPGRFA and CBD emphasize the continuum between conservation and sustainable utilization, along with facilitated access and equitable sharing of benefits arising from use.

In addition, all accessions should be accompanied with the required documentation such as phytosanitary certificates and import permits, as relevant according to the IPPC. The final destination and the latest phytosanitary import requirements for the importing country (in many countries, regulations are changed frequently) should be checked before each shipment. Germplasm transfer should be carefully planned in consultation with the national plant protection organization or the officially authorized institute, which needs to supply the appropriate documentation, such as an official phytosanitary certificate, complying with the requirements of the importing country. The recipient of the germplasm should provide the supplying genebank with information concerning the documentation required for the importation of plant material, including phytosanitary requirements.

Vegetative materials from a field genebank accession should be subjected to therapy and indexing procedures before being distributed to germplasm users. Indexing for difficult to detect pathogens, such as viruses, is important for limiting their spread. When virus indexing capabilities are unavailable, in particular for material known to have come from virus-infected areas, the sanitary status should be attached to the passport data and the material distributed if the recipient has a quarantine facilities or if it meets the criterion of the import permit of the requesting country or region.

The type of shipping container, packing materials and the choice of shipping company will depend greatly on the plant part to be distributed. Phytosanitary certificates and quarantine and import permits often document how the specific germplasm has to be packaged and shipped. Dormant or storage organs require fewer precautions and may spend a longer time in transit without damage than actively growing propagules. Accessions should be kept separate during shipment; they must not mix. Standard operating procedures (SOPS) available in many genebanks cover technical issues such as packaging, treatment, shipping method, sample size, etc. and should be referred to.

Timing shipments to avoid severe weather (either hot or cold) and notifying the recipient or customs official prior to the plant's arrival will improve the likelihood that the plants will arrive in good condition. Fragile propagules may require express delivery services. International shipments are facilitated if necessary papers are attached to the outside of the container for easy access by officials without disturbing the plants, with copies inside for the recipient. The requestor may need to purchase services of a courier to carry the germplasm through customs into the country.

All accessions should be accompanied with the minimum information necessary to the requester to make appropriate use of the material. This information should include at least an itemized list, with accession identification, number and/or weights of samples, and key passport data. In addition, the pathogen testing history is usefully included. Distribution records (records with date of request, plants requested, plant form, requester's name and address, shipment date and shipping cost) should be maintained and included in the genebank's documentation system (see standards for documentation). Distributed plant material may become a source of propagative material in case of a catastrophic loss of original material at the originator genebank.

Contingencies

Simultaneous conservation of accessions *in vitro* provides protection from pests, pathogens and climatic hazards and increases their availability for distribution if the materials are maintained virus free. In some cases, such as cassava (*Manihot esculenta* L.) and cacao (*Theobroma cacao* L.) cuttings from field banks can generally only be disseminated within a country, and sometimes only within certain regions of a country, due to pest and disease quarantine regulations. Other forms of propagation, e.g. *in vitro* cultures or seeds should be used to exchange germplasm between countries or quarantine regions. Distribution of materials from greenhouses or screenhouses may be necessary for crops with insect- or mite-borne viruses and *in vitro* cultures may be required.

Political decisions, crisis situations or bureaucratic delays might extend the time span between receipt of a sample request and the distribution of the material. Limitations related to regeneration and/or multiplication of the accessions may also affect and delay the distribution process. A delay in checking quarantine regulations until the shipment is ready to send will result in a waste of resources. Consignments of germplasm infested with pests or without proper documentation will be refused entry into the importing country or be destroyed.

SELECTED REFERENCES

SGRP-CGIAR. Crop Genebank Knowledge Base. Distribution (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=59&Itemid=208&lang=english).

5.10 Standards for security and safety duplication

Standards

5.10.1 A risk management strategy should be implemented and updated as required that addresses physical and biological risks identified in standards.

5.10.2 A genebank should follow the local Occupational Safety and Health (OSH) requirements and protocols.

5.10.3 A genebank should employ the requisite staff to fulfil all routine responsibilities to ensure that the genebank can acquire, conserve and distribute germplasm according to the standards.

5.10.4 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.

Context

Given that a field genebank is a live assemblage of plants collected from different areas that will stay in one location for many years, it is extremely vulnerable to a number of threats, including environmental conditions, pests and diseases, land tenure and land development. A field genebank is also expensive to maintain and requires constant care compared to other means of conservation. It should implement and promote systematic risk management that addresses the physical and biological risks in the every day environment. This standard provides the elements which a genebank need to fulfil in order to secure the collection for these threats and ensure that no loss in genetic diversity occurs.

Technical aspects

A field genebank should have in place a written risk management strategy on actions that need to be taken whenever an emergency occurs in the genebank concerning the germplasm or the related data. This strategy and an accompanying action plan should be regularly reviewed and updated to take advantage of changing circumstances and new technologies, and be well publicized among the genebank staff.

Field genebanks are exposed to many threats. These include extreme weather conditions like drought, freezing, hail, cyclones, typhoons, hurricanes, which are partially predictable and precautions can be undertaken to give plants additional protection during unfavourable periods. If plants are held in pots, they can be taken into a sheltered place. For smaller plants in the open field, depending on the plant type, little can be done except for reinforcing stakes or covering with a protective cover where feasible. For fruit trees, pruning branches can be done to reduce the impact of strong winds that may lead to the uprooting of trees.

Other extreme events such as fire outbreaks or earthquakes are hardly predictable and, in such cases, precautionary measures to prevent damage to plants in the field genebank need to be taken. Fire breaks across the field genebank need to be established and maintained at all times. In addition, fire-fighting equipment has to be in place and regularly checked. Fire-fighting equipment will include extinguishers and fire blankets. Field genebank buildings including greenhouses and nurseries need to be earthquake-proof if situated in a seismic-prone area.

Other threats to field collections relate to biotic factors including pests and diseases, predators, alien species, rodent pests and native material of the same species growing wild in the area that can enter the field as weeds. Precautionary measures need to be taken against these threats. Pesticides should be used with caution as this not only has a negative impact on the environment, but also on the health and safety of personnel applying these. Where appropriate, the use of traps to catch predators or ditches to prevent access to the plots can be more ecologically friendly and the invasion of animals into field genebanks should be avoided by using humane protocols approved by relevant societies.

Vandalism or theft of planting material can also be major problem to the security of collections. Field genebanks should be appropriately fenced and access to the premises of the field genebank should be well controlled. In some places, additional security guards or security fencing may be required. Considering the long-term nature of field genebanks, especially for fruit and other tree species, securing the land tenure and development plan for the site is important to reduce the need for moving to a new site and to allow expansion.

The occupational health and safety of the staff should also be considered. Properly functioning protective equipment and clothing should be provided and used in the field, especially when using chemical pesticides and fertilizers. Choice of agrochemicals is important to reduce risk. A list of chemicals that are generally safe for various crops and a "black list" of chemicals that are dangerous and are forbidden should be established. Staff should be instructed in the correct and safe use of equipment with regular training provided in health and safety in field environments.

Active genebank management requires well-trained staff, and it is crucial to allocate responsibilities to suitably competent employees. A genebank should therefore, have a plan or strategy in place for personnel, and a corresponding budget allocated regularly so as to guarantee that a minimum of properly trained personnel is available to fulfil the responsibilities of ensuring that the genebank can acquire, conserve and distribute germplasm. Access to disciplinary and technical specialists in a range of subject areas is desirable, depending on the mandate and objectives of each individual genebank. However, staff complements and training will depend on specific circumstances. Staff should have adequate training acquired through certified training and/or on-the-job training and training needs should be determined as they arise.

The use of complementary conservation methods for safety duplication of accessions maintained in field genebanks is an important strategy to reduce risk mentioned above and may be more economical. Accessions may be backed up as slow-growth *in vitro* cultures or cryo-preserved in LN, whenever protocols for the target accessions are available. For those species that produce short-lived or recalcitrant seeds, short-term seed storage, where seeds are renewed before viability is lost, is a feasible and cost effective backup method. A duplicate field genebank in another area with a suitable climate and agroecology where the plants will thrive, but that is not subject to the risks of the main genebank, can also be used for safety backup. It also provides an additional site from which material can be distributed and can be located in an area with different pest and disease risks for safety of the collection and to ease quarantine restrictions for distribution within regions. Pollen and DNA storage also complements field genebanks by providing a cost effective way to maintain a larger amount of diversity within an accession than can be maintained as plants in the field genebank.

Any safety duplication arrangement requires a clear signed legal agreement between the depositor and the recipient of the safety duplicate that sets out the responsibilities of the parties and terms and conditions under which the material is maintained. This is particularly important for field genebanks where the plants have to be managed on a daily basis.

Contingencies

When suitably trained staff is not available, or when there are time or other constraints, the solutions would be to include outsourcing some of the genebank work or approaching other genebanks for assistance. It is important to develop networks and collaborations with other genebanks. The international community of genebanks should be instantly informed, if the functions of the genebank are endangered.

Unauthorized entry to genebank facilities by humans or incursion of animals, including birds and other wildlife can result in direct loss of material, but can also jeopardize the collections through inadvertent introduction of insect pests and diseases and interference in management systems. Working closely with local communities to raise awareness of the purpose and value of the collection can give a sense of ownership and increased protection to the field area.

SELECTED REFERENCES

Engels, J.M.M. & Visser, L., eds. 2003. *A guide to effective management of germplasm collections*. Handbooks for Genebanks No. 6. Rome, IPGRI.

NordGen. 2008. *Agreement between (depositor) and the Royal Norwegian Ministry of Agriculture and Food concerning the deposit of seeds in the Svalbard Global Seed Vault*. The Svalbard Global Seed Vault. The Nordic Genetic Resource Centre, ALNARP (available at: http://www.nordgen.org/sgsv/scope/sgsv/files/SGSV_Deposit_Agreement.pdf).

Reed, B.M., Engelmann, F., Dulloo, M.E. & Engels, J.M.M. 2004. *Technical guidelines for the management of field and* in vitro *germplasm collections*. Handbooks for Genebanks No. 7. Rome, IPGRI.

SGRP-CGIAR. Crop Genebank Knowledge Base. Safety duplication (available at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_ content&view=article&id=58&Itemid=207&lang=english).