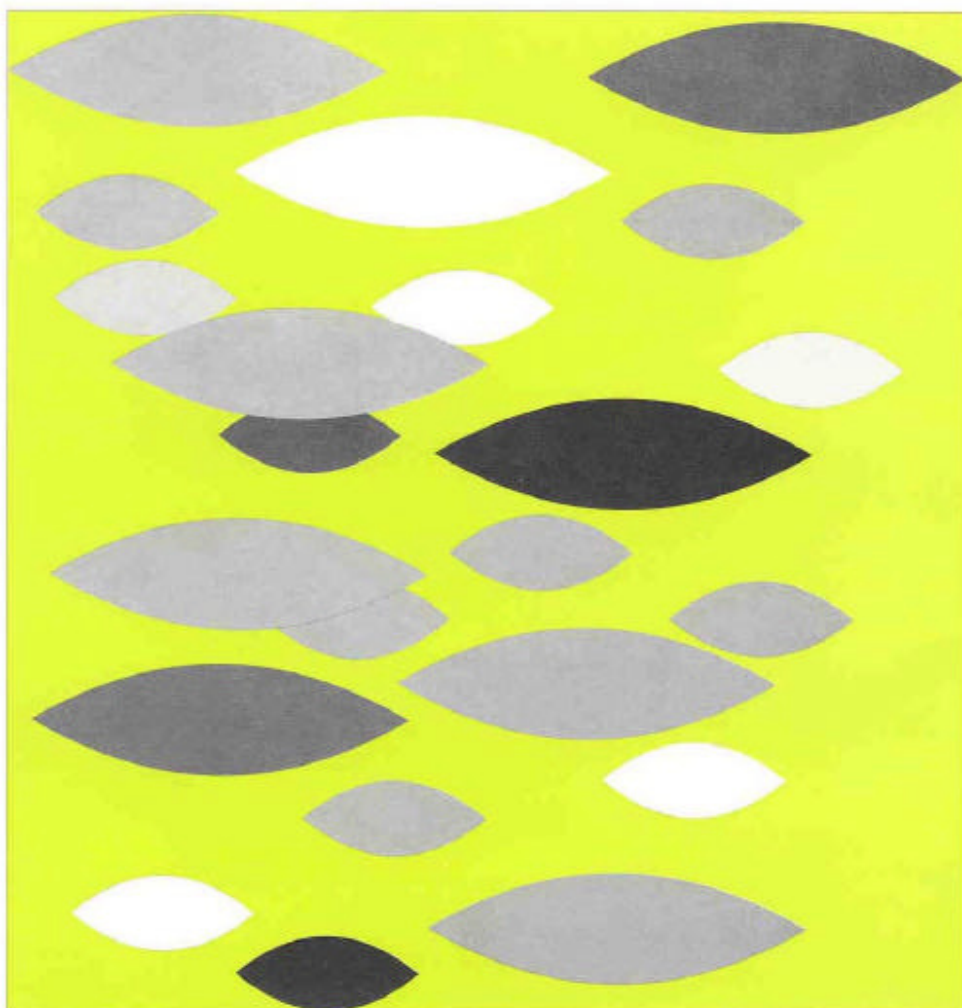

Genebank standards



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PREAMBLE

FAO and IBPGR have been cooperating since the early seventies to strengthen national capabilities in *ex situ* conservation of plant genetic resources, including the development of agreements and network activities with institutions that had accepted primary responsibility for long-term conservation of germplasm of particular species in their base collections.

The International Undertaking on Plant Genetic Resources, which was approved by FAO member countries in 1983, requests that: "there develops an internationally coordinated network of national, regional and international centres, including an international network of base collections in genebanks, under the auspices or the jurisdiction of FAO, that have assumed the responsibility to hold, for the benefit of the international community and on the principle of unrestricted exchange, base or active collections of the plant genetic resources of particular plant species". FAO and IBPGR have agreed to merge the IBPGR register of base collections with the international network, within the context of the Global System for Conservation and Utilization of Plant Genetic Resources.

In 1991, the Commission on Plant Genetic Resources considered it "essential that appropriate standards be developed for genebanks operating within the international network". The Commission requested "the convening of a panel of technical experts, to work in collaboration with FAO and IBPGR to assess and, if necessary, redefine genebank standards". It also agreed that the standards should take into account the advances in seed storage technology and the requirements of seeds of wild species.

Subsequently, an FAO/IBPGR Expert Consultation was convened in 1992 to discuss and update the genebank standards that IBPGR published in 1985. The Genebank Standards recommended by the Expert Consultation were then endorsed by the 5th Session of the Commission on Plant Genetic Resources in April 1993.

FAO and IPGRI recommend that these standards be widely utilized as the international reference in national, regional and international genebanks.

I. INTRODUCTION

1. These Genebank Standards are based on the Report of the FAO/IBPGR Expert Consultation Group on Genebank Standards held in Rome, Italy, from 26 to 29 May 1992. The Group was convened in order to further refine International Standards for Genebanks to minimize the loss of genetic integrity in seed accessions during storage and regeneration using the Report of the Third Meeting of the IBPGR Advisory Committee on Seed Storage (AGPG/IBPGR/84/74, April 1985) as the basis of its discussions. Particular attention was paid to providing standards which would apply to wild species and to forest tree species as well as to crop species. A list of the members of the Expert Consultation is provided in Appendix I.

2. The Genebank Standards are concerned solely with the storage of seeds of orthodox species: that is those species whose seed can survive very considerable desiccation, and in which longevity is dramatically improved by reducing seed storage moisture content and/or temperature.

STANDARDS

3. Standards are essential in order to provide targets for institutes to aim at. However, the problems inherent in setting standards should be noted. On the one hand, there is the problem that the standards set now may limit future technological advances; in other words, the global genebank network may become fixed at one level. On the other hand, there is the problem that some institutes may be unable to meet the standards specified herein. In view of these problems, in some cases two standards are specified:

- (i) acceptable - in many cases minimal but considered adequate (at least in the short-term); and
- (ii) preferred - a higher and thus safer standard.

4. For most criteria there are good scientific reasons for meeting the "preferred standards". Therefore, efforts should be made to achieve such standards. However, where resources are limited it would be possible for curators to reach pragmatic compromises such that even under operating conditions that were not ideal, the collection would not be placed in jeopardy. The aim should be to store as many accessions as possible in an acceptable manner rather than a few at the preferred standard. Long-term safe and sustainable conservation efforts are the ultimate objectives.

5. A particular problem has been associated with the wrong perception that if a genebank operated at a standard less than the ideal target its conserved germplasm was automatically considered to be in jeopardy. Recent research on seed storage and archaeological findings have indicated the potential of storing seeds of many crop species and retaining viability for more than a century at a seed moisture content of around 5% under a storage temperature of about +5° C. This storage standard is considered acceptable for conserving germplasm, although there are alternative standards, based on different combinations of

storage temperature and seed moisture content, to realistically achieve the purpose of long-term germplasm preservation. An attempt has been made to propose standards that can preserve germplasm for a reasonable period. However, all genebanks are encouraged to try to achieve the preferred standard recommended.

TERMINOLOGY

6. The base collection is defined as a set of accessions, each of which should be distinct and, in terms of genetic integrity, as close as possible to the sample provided originally, which is preserved for the long-term future. The base collection for a crop genepool or any species may be dispersed among several institutions - a practice which is likely to increase with the development of crop networks. Normally, seeds will not be distributed from the base collection directly to users.

7. Active collections comprise accessions which are immediately available for multiplication and distribution for use. It is not, therefore, the role of base collections to provide seed samples to users: normally these would be provided via active collections. The terms "base collection" and "active collection" are not synonymous with the conditions under which the seeds are stored. However, in order to preserve base collections it is usual to maintain such collections under long-term seed storage conditions. There is no fundamental reason why active collections should not also be kept under long-term conditions but, because such collections are often accessed frequently, they are often maintained under medium-term storage conditions.

8. The Standards do not provide a detailed account of genebank construction and management. There are numerous publications available from FAO/IBPGR which provide detailed guidance on many aspects of genebank design and operation (see Appendix II).

II. STANDARDS FOR SEED STORAGE

Control of environmental conditions

9. There is a need to maintain seeds under the best possible conditions before storage, to maintain high levels of viability of germplasm entering active and base collections. The seeds should be held for the minimum amount of time under temporary conditions that do not meet acceptable standards for conservation.

10. There is no known benefit in chemically treating seeds during storage at the preferred conditions of storage for base collections to control pests and diseases. Such chemicals may even cause chromosomal damage or be against health and safety regulations for personnel. Chemicals may be necessary during regeneration to ensure that healthy seeds are produced, or for post-harvest treatment, especially in tropical countries.

11. Attention should be given to the environmental conditions of the seed processing area. In tropical areas with high ambient humidity, it may be necessary to have an ancillary room with controlled humidity and temperature to avoid condensation on the seeds during

packing. Use of psychometric charts is recommended to decide which action is required to avoid condensation.

Seed Drying Procedures

12. The objective in drying seeds is to reduce the moisture content to a level which prolongs longevity during storage and therefore increase the regeneration interval. A variety of methods can be used for seed drying, the most common being the use of a desiccant or dehumidified drying chamber. The methods chosen will depend on the available equipment, number and size of the samples to be dried, local climatic conditions and cost considerations.

- (i) Drying at 10-25°C and 10-15% relative humidity (r.h.) using either a desiccant or drying chamber is preferred.
- (ii) Silica gel is suitable for seed drying and can be used to reach the very low moisture contents of ultra dry seed.
- (iii) Seeds need to be dried as soon as possible after reception to avoid substantial deterioration. The length of the drying period will depend on the size of the seed, the quantity being dried, the initial seed moisture content and the relative humidity in the drying room.

13. Genebank personnel should note that dry, and especially very dry, seeds are often brittle and thus prone to mechanical damage. Hence, seeds in genebanks should always be handled with care.

Seed Cleaning and Health

14. Seeds for storage in germplasm collections should be as clean and free from weed seeds, pests and diseases as possible. It has been reported that seed borne diseases affect longevity during storage. Curators should be aware of this potential problem, although no specific recommendations could be given at this time.

STORAGE CONTAINERS

15. A range of containers is now available which are moisture-proof and sealable. Choice of container will depend on availability and quality to withstand the storage conditions in the long term without leaks. When in doubt about the vapour exchange properties of containers, it is recommended that tests should be done to ensure that no moisture exchange occurs. It should be noted that many plastics are not moisture proof.

16. The use of any type of sealed moisture-proof containers, which are tested regularly to ensure quality of both material and seal, is acceptable. Storage of seeds of individual accessions in multiple containers for extra security is preferred. Some concern has been

expressed that toxic gases may be produced in long-term storage which may affect the longevity of the seeds. However, at the low moisture contents and temperatures preferred for storage of base collections, metabolic and autocatalytic activity would be reduced to such low levels that the release of toxic gases would not reach a level at which there is any significant effect on seed longevity.

SEED STORAGE CONDITIONS FOR BASE COLLECTIONS

17. Acceptable: Sub-zero temperatures ($<0^{\circ}\text{C}$) with 3-7% seed moisture content (depending upon species).
Preferred: -18°C or cooler with 3-7% seed moisture content (depending upon species).

The above seed moisture content standard may need to be raised in exceptional cases where there is strong evidence that problems can arise at this moisture content (e.g. seed breakage during seed handling).

18. The preferred standards for storage of -18°C or less with about 5% moisture content should not be relaxed. However, it should be emphasized that the choice of seed storage conditions by an individual genebank depends upon the species stored and the length of storage period envisaged before regeneration is likely to be required. Hence some flexibility is required with regard to what should be considered acceptable, particularly for those circumstances in which refrigeration to the extent required by the above preferred standard cannot be provided. Owing to the nature of the relation between seed longevity, storage temperature and seed moisture content, the same storage life can be achieved by different combinations of temperature and moisture.

19. The tendency to overemphasize the benefits of reduction in temperature compared to those in moisture content should be avoided. With regard to the effect of temperature, the relative response of longevity to reduction in seed storage temperature is very similar among diverse orthodox species, but the relative benefit of a given reduction in temperature becomes less as temperature is reduced (at least, that is, within the ranges usually investigated down to -20°C). Thus, longevity is increased by a factor of almost 3 if storage temperature is reduced from 20°C to 10°C ; by 2.4 from 10°C to 0°C ; by 1.9 from 0°C to -10°C ; but by only 1.5 from -10°C to -20°C .

20. In contrast, the relative benefit to longevity of reduction in moisture content: (i) varies among species; and (ii) becomes greater for each successive reduction in moisture content. This variation among species appears to be largely a function of difference in seed composition (which influences the equilibrium relation between seed moisture content and relative humidity).

21. A calculation which was made some years ago (but which, like many calculations involving extended periods of longevity, is to some extent based on extrapolation) to put the relative benefits of reduction in each of storage temperature and moisture content in context concerns the crop sesame (*Sesamum indicum* L.). The effect of a reduction from 5% to 2% seed moisture content provides about a forty-fold increase in longevity. This is

about the same relative benefit as a reduction in temperature from +20°C to -20°C. However, in most crops the benefit of desiccation to longevity does not extend to such low moisture content values.

22. There is a low-moisture-limit to the increase in longevity observed to occur with reduction in seed storage moisture content. The value of this limit varies among species, but it is thought that this variation is also related to differences in seed composition such that equilibrium relative humidities at the critical moisture content are similar for different species. One estimate of this value is moisture contents in equilibrium with about 10 - 12% r.h. at 20°C. It is reasonable to maximize the benefit of desiccation to subsequent longevity by drying seeds to 10 - 12% r.h. at 20°C and then storing hermetically at ambient, but preferably cooler temperatures, if the storage temperature could not be controlled, or where the reduction in temperature provided by refrigeration is not adequate to meet the preferred standard for temperature. This approach has been previously described as "ultra-dry storage". However, in some species this standard is actually slightly greater than the original 5% standard (e.g. 6-6.5% moisture content in pea).

23. Whether seeds are stored dry or ultra-dry, it is essential that all seeds be "conditioned" or "humidified" (by placing in a very moist atmosphere, usually overnight but occasionally slightly longer in the case of very large seeds) prior to testing for germination or growing out.

SEED STORAGE CONDITIONS FOR ACTIVE COLLECTIONS

24. Active collections should be kept in conditions which would ensure that accession viability remain above at least 65% for 10 to 20 years, being the only standard which should be provided. The precise storage regimes used to fulfil this objective will vary depending upon the species stored, the prevailing ambient environment and the relative local costs of (principally) electricity and labour. As indicated in the preceding section, different combinations of storage temperature and moisture can provide the same longevity. However, it could be emphasized that, in most locations, the reduction and control of seed storage moisture content will be a more cost-effective approach than controlling temperature.

ACCESSION SIZE IN BASE COLLECTIONS

25. It would be difficult to fulfill the function of a base collection unless accession size is sufficient to enable the accession to be regenerated, to provide an adequate sample to at least one active collection without regeneration, and to allow at least a few monitoring tests of viability.

Acceptable: 1,000 viable seeds within the accession in store is considered an absolute minimum. It is accepted that any single number is, of course, arbitrary. In cases where fewer than 1,000 seeds are available, then the accession may nevertheless have to be accepted into good storage conditions until such time as it is possible to recollect or to regenerate.

Preferred: 1,500 - 2,000 viable seeds.

It is recognized that more seeds will be necessary in the case of genetically heterogeneous accessions.

VIABILITY MONITORING

26. Genebank managers have the responsibility to provide conditions which will maintain the viability of each accession held within the genebank above a minimum value. Hence accession viability must be monitored. The preferred standard is that this obligation extends not just to the genebank, which can be considered the originator of the accession, but also to those genebanks holding a duplicate of the accession.

27. Viability will usually be assessed by means of a germination test, although other test procedures (such as the topographical tetrazolium test) may be required in order to clarify whether the non-germinating seeds in these tests are non-viable or whether their dormancy has not been broken during the test. Empty seeds not already removed before storage should be removed before beginning the germination test. An IBPGR handbook (Appendix II, IBPGR, 1985) is available which provides both general and specific advice on the conduct of germination tests and appropriate dormancy-breaking procedures.

28. The minimum standard is that accession viability monitoring tests be carried out at, or soon after, receipt and subsequently at intervals during storage. The initial germination test should be carried out on a minimum of 200 seeds drawn at random from the accession.

29. The period between viability monitoring tests will vary among species and will also depend upon the seed storage conditions. Genebanks should regularly conduct monitoring tests. Under the preferred storage conditions for base collections, the first monitoring test should normally be conducted after 10 years for seeds with high initial germination percentage. Species known to have poor storage life or accessions of poor initial quality should be tested after 5 years. The interval between later tests should be based on experience, but in many cases may well be greater than 10 years. Note that where the preferred conditions of storage are not being met, then monitoring may need to be more frequent. Where a genebank has been operating for some years under the preferred conditions and has obtained sufficient information from their own monitoring tests on the range of material they work with to justify more extended monitoring intervals then this should be done.

30. The objective of the viability monitoring test is to decide whether regeneration is required. It is recommended that, in order to save seeds, 50 - 100 seeds be drawn at random from the accession for each monitoring test. The simplest method of determining whether substantial loss in viability is occurring, and distinguishing between this and the fluctuation in test results which is largely a consequence of sampling error, is to plot the results of successive monitoring tests against the period of storage and to see whether a progressive trend of loss in viability can be detected.

Where such an indication is obtained, it is recommended that, provided sufficient seeds are available, a further sample of 100 seeds are drawn at random for a further viability monitoring test to reduce the probability that regeneration is initiated prematurely. Once it has been decided that an accession should be regenerated, further germination tests should be suspended to save valuable seeds.

31. It is essential that genebanks have, or have access to, sufficient laboratory equipment to enable viability monitoring tests to be carried out in a regulated, uniform and timely manner. In some cases the particular problems of the species maintained will require the provision of more specialized equipment, e.g. X-ray equipment to test for empty seeds and/or insect-damaged seeds.

32. Initial germination testing and viability monitoring during storage requires adequate facilities to carry out these tests according to the conditions described in paragraphs 27 to 31. It is acceptable that a base collection should have access to suitable seed testing facilities and it is preferred that these should be at the same site as the base collection.

33. In the case of active collections, it is suggested that monitoring every 5 years will normally be satisfactory. However, this should be adjusted up or down depending upon the species stored, initial viability, and the storage environment. Where base and active collections are maintained side-by-side within the National Agricultural Research System under the preferred conditions for base collections then the advice for base collections should be followed for the active sample and in most cases it will not be necessary to sample from the base collection until the results for the active collection sample suggest this is necessary, or the latter becomes depleted. Note that this comment only applies in situations where the base and the active collections represent the same original seed sample which has simply been divided at random into the base and active samples.

34. There is no non-destructive viability monitoring test currently available. It is recommended that where the number of seeds within an accession is limited, and regeneration is feasible, the seedlings produced during accession viability monitoring tests should be grown out to provide a fresh stock of seeds (e.g. for distribution) providing, of course, that the number of seedlings available is sufficient for regeneration.

REGENERATION

35. Regeneration standards are needed to ensure that the seeds stored in base collections do not fall below acceptable levels of viability and yet minimize the number of regeneration cycles to ensure that the genetic integrity of accessions is maintained. The regeneration interval will depend on the longevity of the seed in storage and demand for the accession (if seeds are not available from an active collection).

36. Seeds which are produced for storage in base collections should, as far as possible, be of the highest possible viability and free of pests and diseases. Recognizing that the initial germination capacity will depend on the environment during production and processing, maturity and physiological state of the seeds at harvest and genetic differences between species, initial germination values should exceed 85% for most seeds, e.g. cereals, and

75% for some vegetables and even lower for some wild or forest species, which do not normally reach high levels of germination.

37. Regeneration should be undertaken when viability falls to 85% of the initial value. Regeneration methods should follow the standards for the crop, where available, and ensure that sufficient plants are used to maintain the genetic integrity of the accession. As far as possible all sources of selection pressure should be removed, the contribution of seeds from each plant should be equalized and all possible care taken to minimize genetic change.

38. It is desirable to use 100 plants or more for regeneration to avoid the probability of large losses of alleles. However, in wild species this may be limited by the total number of seeds available. Wild species may also vary in breeding system, storage behaviour and germination from the related crop species. This should be taken into consideration when deciding when, and how to regenerate an accession.

39. In order to ensure that the genetic integrity is maintained and accessions are distinct, it is recommended that seeds used to plant material for regeneration should be as close as possible genetically to the original germplasm. It is recommended that for active collections, regeneration should be done from original seeds whenever possible or from its offsprings within two or three cycles of regeneration to ensure that genetic integrity is maintained. This implies that, assuming a 15 year storage cycle for the active collection, seeds for regeneration will need to be taken either from the base collection or other original seed in long-term storage once in 45 to 60 years, providing sufficient seeds are regenerated to meet demands on the active collection for distribution. Genebanks carrying out regeneration should also consider what methods they could use to monitor variation during regeneration to measure any changes in genetic constitution in accessions.

INFORMATION ABOUT BASE COLLECTIONS

40. Information about the accessions in the base collection is an essential part of the base collection because good information will enhance the usefulness of the germplasm. Data on any accession should be as complete as possible in order to identify it as a distinct accession, although accessions without extensive data are also valuable and it may be justified to include them in base collections.

41. There are five major types of data relating to accessions held in base collections:

- i. Passport
- ii. Management
- iii. Characterization
- iv. Evaluation
- v. Mode of reproduction

42. The standard descriptors for passport and management data are presented in Appendix III. As a minimum, each accession should be accompanied by available passport and management data and mode of reproduction (if known). In many cases individual accessions will vary with regard to mode of reproduction within a species. It is preferred that characterization and evaluation data on the accessions should also be held by base collections or be readily available from other sources.

III. STANDARDS FOR THE EXCHANGE AND DISTRIBUTION OF SEEDS FROM ACTIVE COLLECTIONS

43. Standards for seed exchange:

- (i) Seeds should be sent out in the most suitable containers available in order to avoid deterioration in transit. Ideally these would be moisture-proof, but it is accepted that different decisions will be made on the basis of the packaging materials available, the likely delays to delivery and the several ambient environments the seeds will be exposed to during transit.
- (ii) Adequate information, such as passport data and (if required) evaluation data should accompany the sample.
- (iii) Special details of germination methods and mode of reproduction (where known) should be provided.
- (iv) A sufficient number of viable seeds should be sent out in order to provide a genetically representative sample of the accession.
- (v) Quarantine and other seed health requirements must be satisfied.

GENEBANK PERSONNEL AND TRAINING

44. Staff numbers: Considering the complexity of the different activities in both base and active collections, the range of species likely to be encountered, and the range of standards of staff training, it is misleading to quote numbers of staff. Similarly, among the specialist scientific staff required, it is not considered helpful to rank the different specializations in any particular order. Among the various disciplines (not ranked in any order), genebanks should have access to expertise in seed physiology, genetics, taxonomy, information management, plant pathology, engineering/maintenance and of course to various crop/species specialists as appropriate.

SAFETY AND SECURITY

45. Every effort must be made to ensure the safety and security of the germplasm in collections through adequate construction, maintenance and security controls of the

installation. Equipment should undergo regular preventative maintenance and trained maintenance personnel are essential for this. Genebank personnel should also be trained in safety procedures to minimize the risk to the germplasm in base collections.

46. The following points should be noted:

- (i) Power Supply to the Seed Store: A stable and continuous power supply is acceptable. An alternative power supply is preferred; normally this would be a back-up generator with adequate fuel supply.
- (ii) Fire Precautions: All reasonable fire precautions should be taken and equipment tested from time to time. Particular attention should be paid to maintaining appropriate fire fighting equipment and training personnel in its use. The installation of a lightning conductor rod, alarm system and high temperature cut out for the cooling system (mounted behind a wall) is recommended.
- (iii) Security: The installation should be designed for high security and adequate security arrangements should be made for the protection of the facility.
- (iv) Refrigeration Standards and Equipment: Refrigeration standards and equipment should conform to the Design of Seed Storage Facilities for Genetic Conservation ("DSSF") (IBPGR 1982) specifications. There should be trained personnel and spare parts available for repair and maintenance. Routine preventative maintenance should be carried out. A back-up refrigeration system is preferred.
- (v) Construction and Insulation: The construction and insulation standards should follow the guidance given in "DSSF", taking into account the local conditions and, wherever possible, using locally available material. The size of the store should reflect the numbers and sizes of germplasm samples to be stored for efficiency. The use of modular units to increase flexibility and safety is appropriate.
- (vi) Safety of Personnel: Protective clothing should be provided and used in the store. Personnel should be aware of and trained in safety procedures. Adequate precautions should be taken and safety equipment including alarms and devices to open doors from inside drying rooms and refrigerated rooms should be installed.

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APPENDIX II

RELATED FAO/IBPGR PUBLICATIONS

- FAO, 1974. Proposed standards and procedures for seed storage installations used for longterm conservation of base collections. FAO, Rome.
- FAO, 1985. A Guide to Forest Seed Handling. FAO Forestry Paper 20/2. FAO, Rome. (Available in English, French and Spanish).
- FAO, 1991. Report of the Fourth Session, Commission on Plant Genetic Resources. FAO, Rome.
- IBPGR, 1982. Design of Seed Storage Facilities for Genetic Conservation. Revised 1985 and 1990. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1985. Handbook of Seed Technology for Genebanks. Volume I. Principles and Methodology. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1985. Handbook of Seed Technology for Genebanks. Volume II. Compendium of Specific Germination Information and Test Recommendations. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1985. Procedures for Handling Seeds in Genebanks. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1985. Cost-effective, Long-term Seed Stores. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1985. Information Handling Systems for Genebank Management. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1989. Regeneration and Multiplication of Germplasm Resources in Seed Genebanks. International Board for Plant Genetic Resources, Rome.
- IBPGR, 1993. Descriptors for white clover (*Trifolium repens L.*) International Board for Plant Genetic Resources, Rome (in press).

APPENDIX III

DESCRIPTORS FOR PASSPORT AND MANAGEMENT PARAMETERS

PASSPORT DESCRIPTORS*

1. ACCESSION DATA

Accession number; donor name; donor number; other number(s) associated with the accession; scientific name (genus, species, subspecies, botanical variety); pedigree; cultivar name; acquisition date; date of last regeneration or multiplication; accession size; number of times accession regenerated; number of plants in each regeneration.

2. COLLECTION DATA

Collecting institute(s); collector's number; collection date of original sample; country of collection; province/state; department/county; collection site; conservation status.

MANAGEMENT DESCRIPTORS*

M1. MANAGEMENT DATA

Accession number; population identification; location in storage; date place in storage; initial germination (%); date of last germination test; germination at the last test (%); date of next test; moisture content at harvest (%); moisture content at storage (initial) (%); amount of seed in storage(s) (number); duplication at other location(s).

M2. MULTIPLICATION/REGENERATION DATA

Accession number; population identification; field/plot/nursery/glasshouse number; location; collaborator; sowing date; sowing density; fertilizer application; germination in the field (%); number of plants established; agronomic evaluation; previous multiplication and/or regeneration (location, sowing date, plot number); others.

* For details see IBPGR Descriptors for White Clover (1993)