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Held in Rome
6-10 April 1981

FAO/UNEP/IBPGR INTERNATIONAL CONFERENCE ON CROP GENETIC RESOURCES

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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ON

CROP GENETIC RESOURCES

Rome, 6-10 April 1981

UNITED NATIONS ENVIRONMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

INTERNATIONAL BOARD FOR PLANT GENETIC RESOURCES

ROME, 1981

ACRONYMS

AAASA	-	Association for the Advancement of Agricultural Science in Africa
CATIE	-	Centro Agronómico Tropical de Investigación y Enseñanza (Costa Rica)
CGIAR	-	Consultative Group on International Agricultural Research
CIAT	-	Centro Internacional de Agricultura Tropical (Colombia)
CIP	-	Centro Internacional de la Papa (Peru)
EEC	-	European Economic Community
EUCARPIA	-	European Association for Research on Plant Breeding
EXIR	-	Executive Information Retrieval
FAO	-	Food and Agriculture Organization of the United Nations
IBPGR	-	International Board for Plant Genetic Resources
ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics
IICA	-	Instituto Interamericano de Ciencias Agrícolas
IITA	-	International Institute of Tropical Agriculture
IRRI	-	International Rice Research Institute
IS/GR	-	Information Sciences/Genetic Resources
ISTA	-	International Seed Testing Association
IUCN	-	International Union for Conservatioa of Nature and Natural Resources
NSSL	-	National Seed Storage Laboratory (USA)
NVRS	-	National Vegetable Research Station (UK)
SABRAO	-	Society for the Advancement of Breeding Researches in Asia and Oceania
SAS	-	Statistical Analysis System
UNEP	-	United Nations Environment Programme
UNESCO/MAB	-	United Nations Educational, Scientific and Cultural Organization/ Man and the Biosphere Programme
UNHCR	-	Office of the UN High Commissioner for Refugees
WARDA	-	West African Rice Development Association

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1. OPENING SESSION

1.1 INTRODUCTION

The Fourth Technical Conference on Crop Genetic Resources was held at FAO, Rome, from 6-10 April 1981 under the joint sponsorship of FAO, UNEP and the IBPGR. The programme for the Conference and a list of participants are given in Appendices 1 and 2 respectively.

1.2 ADDRESS OF WELCOME

Dr. O. Brauer, Director of the Plant Production and Protection Division, FAO introduced the representatives of FAO, UNEP and the IBPGR who were to give the addresses of welcome.

(i) Dr. D.F.R. Bommer, Assistant Director General, Agriculture Department, FAO.

Dr. Bommer welcomed participants on behalf of the Director-General of FAO. He reminded the audience that twenty years had passed since the First Conference on Crop Genetic Resources was held in July 1961. Since then deterioration of the environment and loss of resources had gone on apace. Counter-measures had grown, however, on many fronts. The UN Conference on the Human Environment in 1972 and the UN Environment Programme were mentioned.

On the world scene, the eradication of hunger and nutrition was still the most urgent problem. It would require a much wider adoption of high-yielding crop varieties and the spread of crop production technologies; steps that would exacerbate the threat to the genetic diversity on which plant breeders must increasingly depend for further advances.

Dr. Bommer drew attention to milestones along the road towards the conservation of genetic resources: the FAO Technical Conferences on Genetic Resources in 1967 and 1973 in close association with the Gene Pool Committee of the International Biological Programme, the Genetic Conservation Programme of FAO and the EUCARPIA activities on plant genetic resources.

It was a special pleasure to welcome Sir Otto Frankel who had been a leading proponent of genetic resources conservation for many years and Professor Jack Hawkes who initiated the first post-graduate training course on the conservation and utilization of plant genetic resources.

With the establishment of the IBPGR by the CGIAR in 1974, in collaboration with FAO and supported by UNEP, it became possible to undertake and coordinate genetic resources activities on a global scale taking into account crop priorities and regional significance. Dr. Bommer was pleased to observe the presence of Mr. Richard H. Demuth, the first Chairman of the IBPGR whose term of office had just ended.

The Conference would be discussing many technical aspects of genetic resources, not least of which would be the size and scope of collections that were necessary to minimize losses and how to ensure unimpeded availability of genetic resources

to plant breeders. Should there be an obligation established by some kind of international agreement or convention to ensure the maintenance of genetic resources and their free exchange?

Dr. Bommer expressed the readiness of FAO to accept the advice of the Conference and to give its services as required towards a system of understanding that would give plant genetic resources the security they required for the future of mankind.

He wished the Conference success in its deliberations.

(ii) Professor R.J. Olembo, Director, Environmental Management Services, UNEP, Nairobi, Kenya.

Professor Olembo brought greetings to the participants and good wishes for a successful Conference from the Executive Director of the United Nations Environment Programme.

UNEP was created, he said, as a result of the Conference on the Human Environment held in Stockholm in 1972. He recalled the fact that seven statements in the Proclamatory Section of the Declaration touched on matters affecting the welfare of the biosphere and in the Principles of the Declaration, three statements referred to the maintenance and preservation of the natural resources of the earth. Of the 109 Recommendations for Action, which were later to become the agenda for world-wide action in pursuit of the Stockholm spirit, nine dealt specifically with genetic resources of all kinds - micro-organisms, plants, animals and fishes.

Dr. Olembo said that he dwelt on the Stockholm Recommendations in order to remind participants that the philosophy and principles of conserving genetic resources were established several years ago. The task of the present Conference was to review what had been done since then.

FAO had been a pioneer in the field of genetic resources; joined since 1974 by the IBPGR and later UNEP. These organizations would merit most of the credit if progress was found to be satisfactory. The corollary was equally true, however, that they should take a good deal of the blame if any failures were found.

Referring once more to the Stockholm Recommendations, Dr. Olembo said that he would be remiss not to point out that it was Sir Otto Frankel who had been largely responsible for them being defined. He was gratified to see him in the audience.

To indicate the tasks that lie ahead, UNEP working through IUCN and supported by FAO and UNESCO, had published the World Conservation Strategy in 1980.

Dr. Olembo concluded by expressing the hope that the Conference would give further impetus to the efforts that are being made to conserve genetic resources.

(iii) Dr. Lennart Kåhre, Director, Swedish State Seed Testing and Certification Institute, Solna, Sweden

Dr. Kåhre welcomed participants on behalf of the IBPGR and gave a special word of welcome to Sir Otto Frankel and Mr. Richard H. Demuth.

Briefly reviewing the Board's development since it was formed in 1974, Dr. Kahre spoke of the close cooperation that existed between it and the FAO.

In the main, the Board's activities were promotional because its limited budget would only allow financial support to be given to selected programmes on genetic resources and for emergencies. These apart, implementation of genetic resources programmes must remain the responsibility of governments.

The Board's main task, he said, was to stimulate world-wide action and indeed, a global network of activities was now becoming evident.

Priorities for crops and regions had been determined and the concept of base and active collections developed in practice. Thanks to the goodwill and work of many people in many countries, very amicable working relations had been established with many national, regional and international centres.

National and regional programmes on genetic resources were being stimulated according to local circumstances. In those countries that had valuable genetic resources but did not undertake plant breeding, Dr. Kåhre said that the Board would seek with a government's permission to arrange collecting expeditions. He made the point that the collection of indigenous and traditional crop plants should precede rather than follow the introduction of high yielding improved varieties to replace old cultivars.

Evaluation, documentation and exchange of genetic resources were extremely important aspects of plant genetic resources activities in order to bring material into plant breeding programmes as soon as possible.

In conclusion, Dr. Kåhre wished the Conference every success.

He then declared the Conference formally opened and invited Dr. J.T. Williams, FAO Senior Genetic Resources Officer and Executive Secretary of the IBPGR, to give his key-note address on: "International cooperation; the past decade and prospects for the next one".

1.3 KEYNOTE ADDRESS J.T. Williams

The following is a summary of the main themes of the speech.

In the opening addresses of welcome, the speakers referred to previous technical meetings: one at FAO twenty years ago (1961) in this same room, the technical conferences of 1967 and 1973, the International Biological Programme under a Committee headed by Sir Otto Frankel and the UN Stockholm Conference. In all these meetings, the formation of a global network of crop genetic centres was seen to be vitally important and recommendations were made to this effect.

The global network that was envisaged had one main aim - to make freely available to breeders all over the world the genetic resources that are required for their programmes both now and in the future.

It is a salutary thought to recall that up to a decade or so ago, scientists and breeders (predominantly from the developed world) visited in an uncoordinated way regions of crop genetic diversity to replenish stocks that formed the genetic bases of their programmes. The material was collected, evaluated, some of it used and most of it discarded. These regions in which agriculture was primitive were regarded as inexhaustible reservoirs of locally adapted races that could be sampled at will when the need arose.

It was in the 'sixties that alarms were sounded by a number of active groups of agriculturally minded scientists who highlighted the threat to our plant genetic resources as they came to be termed. Landraces were being discarded in many parts of the world to the point of extinction in favour of higher yielding advanced cultivars. Old cultivars, too, which are so often the foundation material for present breeding programmes, were being lost. The wide swing to a technology based agriculture threatened not only landraces but also their wild progenitors and weedy relatives, a large, untapped but potentially valuable sector of genetic diversity. Meantime, the need for wider genetic bases in plant breeding was being realized. There was a growing awareness that crop plants bred on a narrow genetic base would not have protection against diseases equivalent to that given by the multitude of genotypes in a primitive crop. To counter these changes, a global programme was envisaged that would take into account all these sources of genetic diversity and act to conserve them.

Efforts began in the early 'seventies to translate this concept into reality and 1974 saw the birth of the IBPGR, an international organization that was able to begin to carry out recommendations that had been voiced for almost a decade. It might be thought that progress since then was directly proportional to the funds that the IBPGR had at its disposal. This was not strictly so, however, because many countries and a number of agencies have also funded genetic resources work.

The Board, with a Secretariat located at and supported by FAO, acts as a catalyst; its work is mainly promotional. In some instances, it has helped long-standing national efforts based on collections assembled many years ago to become part of the international programme. It encourages a transfer of technology from the developed to the developing countries and tries to promote activities wheresoever they are needed and whenever they can be easily carried out.

With so much to be done, one of the first tasks of the Board was to set priorities for crops and regions. A number of important facts emerged from this first exercise. Even when the origin and evolution of a particular crop was well-known, the actual patterns of variation and distribution in the field were far from clear and rates of genetic erosion were frequently mere guesses. In view of problems like these, the Board appointed committees and working groups to study particular crops and advise on courses of action. Since the first one met over five years ago, action has started or been accelerated on thirty

major crops or groups of crops. In 1980, the Board was in a position to develop a global plan of action; it will be revised if necessary each year.

Wheat was taken as an example to illustrate problems that are raised. One major gap was a knowledge of the extent and scope of existing collections. It was not known how much wild and primitive material they contained though it was suspected that most of the samples were recent cultivars or breeding lines. Neither was the extent of duplication between collections known nor the taxonomic spread of the samples. However, a survey completed in 1980 showed that many species were poorly represented in many major collections. In 1970, it was thought that there were more than 250,000 samples in wheat collections whereas the survey showed that there are no more than 150,000. From this and other surveys, it could be concluded that no major crop has been collected thoroughly although, as will appear from reports during the Conference, comprehensive collections are well on the way to being formed for some of them. Special mention was made of the great collections in the USSR and the USA. Many of the early collections had been made for breeders and research rather than genetic resources conservation.

Although it might have been valuable to organize the global programme on a phytogeographical basis, for practical convenience the Board had used a regional approach: fourteen regions, each made up of a group of adjacent countries. On the whole the idea of a regional centre to serve several countries had not gained wide acceptance, the preference is for national programmes.

Turning from generalizations to specific aspects of genetic resources activities, Dr. Williams said that since 1976 the Board had organized collecting missions in many parts of the world especially for wheat, rice, sorghum, millets, maize, beans, groundnut, cowpea, banana, cotton, coconut and beet. In addition, collecting expeditions had been carried out for some of these crops and for others by regional programmes; those for the Mediterranean, Africa, South, South East and South West Asia and Latin America. In 1979, the Board and FAO supported collecting missions for cereals in 26 countries, for food legumes in 11, for roots and tubers in 7, for fruits in 5 and for forages 5. These figures gave some idea of the magnitude of the task.

At the last Technical Conference, Marshall and Brown had recommended that the sampling strategy for seed crops should focus on locally common alleles and aim to include in the collected samples at least one copy of each allele occurring with a frequency of more than 0.05 percent in the population. Coarse grid sampling is usually followed by more intensive sampling, the target being to collect from 50 to 100 separate plants per site from as many sites as possible and a typical range of environments. All too often, however, records have shown that sampling has been done only along major roads and that the main interest was useful looking plants rather than representative genetic variability.

Substantial collections will have to be maintained said Dr. Williams to embrace the full range of the genetic variability of our crop plants and their wild relatives. Do we need to expand and accelerate collecting? Who is going to do it and pay for it? Dedicated collectors were all too few. These were questions that the Conference might care to consider.

As regards the conservation of collections, the distinction is made between base collections kept at about -18 °C for long-term storage and active collections kept at about 0 °C for medium-term storage.

When a survey of storage facilities was carried out in 1975, there proved to be only eight institutes in the world with refrigerated stores for seeds. By 1978 the number was twenty. It had increased further in recent years to the extent that the Board has been able to start to designate a global network of base collections to safeguard in perpetuity seeds of the major crops. Currently, the network consists of 17 genetic resources centres for 19 crops. By 1985 the network should be complete for the major cereals, legumes and vegetables. However, the distinction between base and active collections was not yet fully appreciated by many and as yet there was not a clearly defined network of active centres associated with the base collections. Considerable expenditure would be needed in the future to provide more refrigerated stores for base collections and to staff and run the ancillary facilities.

Concerning the safety and availability of samples, it was recognized that all collections should have at least one duplicate. More replication would be preferable both for safety and to increase the availability of material. In some of the older collections only small samples of seeds were taken originally and they had not been multiplied subsequently.

Annual crops whose genetic variability could be conserved in seeds had pre-empted the attention of the Board but interest was now being directed towards perennial crops. Some were propagated by seeds, others as clones and some by both methods. For those that were always propagated vegetatively or had short-lived or recalcitrant seeds, plantations were necessary. However, progress was being made towards an understanding of the physiology of short-lived seeds. Indeed, recent work had shown that some of them could be stored; the example of Citrus was cited. The use of in vitro tissue culture for genetic conservation had been mooted for several years but the method was not yet practicable. In any case, plantations of clonally propagated crops would always be necessary if only to allow the breeder to see his material. Quarantine measures were an important consideration in setting up collections of vegetatively propagated crops and in the exchange of material.

Dealing with the evaluation and documentation of collections, Dr. Williams said that a decade ago it was thought that when collections had been made, they would automatically be evaluated and documented by breeders. This has not occurred and many large collections that may contain valuable material are still inadequately described.

One of the major achievements of the IBPGR had been the development and publication of descriptor lists that could be used internationally. About 30 crops had been dealt with so far. The next step was to get the international agricultural research centres, organizations such as EUCARPIA and SABRAO and national programmes to use the descriptors in their cooperative evaluation studies.

In considering information needs for genetic resources, Dr. Williams said that a distinction is now made between passport data that relate to collection and the identification of the sample, characterization data that refer to those characters that are highly heritable and can be expressed and easily seen in all environments and preliminary evaluation data that include a number of additional traits thought to be desirable for particular crops. Evaluation beyond this stage is quite clearly the task of the breeders.

As regards the storage of data, the Board now took the view that any type of data management system could be used to suit local requirements. Exchange of data between genebanks could be by print-outs, tapes or diskettes, the sole requirement being that they were readable or could be converted into a readable form by the recipient.

It was Dr. Williams' conviction that money should not be spent by the Board on any aspects of documentation other than the standardization, storage and retrieval of information until the evaluation of a collection had been done and the information was there to be sorted and used.

About training in genetic resources, Dr. Williams said that the Board would continue at least until 1985 to support the courses on the conservation and utilization of plant genetic resources initiated by Professor Hawkes at Birmingham University, England. By 1980, no less than 100 trainees had taken the courses and thirteen or fourteen graduates were attending the Conference.

The Board had also organized short technical courses on topics such as the identification of wheat species, seed technology for genebank managers and collecting methods.

Finally, Dr. Williams enumerated limitations and difficulties that had to be faced in the future.

What could be done to speed up collecting as time was running out for some species? Could the costly research and development that was needed to evolve an effective method for conserving clonal crops be accelerated? In view of increasing energy costs, should attention be given to methods other than the use of refrigerated cold stores for storing seeds? In this context, it was pleasing to note the proposal by Poland to store material in Antartica and the intention of the Nordic Gene bank to store collections in Iceland. He reiterated the need for active centres to be associated with base collections. Far too many centres were acting simply as seed stores when the need was not only to store seeds well but to evaluate and document the collections and carry out regeneration when necessary.

Dr. Williams thought that it may not be necessary for every country to have a specific genetic resources centre since a few centres could cope with the needs of all. Care would have to be taken not to make the global network of active and base collections so extensive that size would defeat the objectives. Nevertheless, inevitably all countries would have to be involved with genetic resources activities.

In conclusion, he said that considerable progress had been made in the last six years since international action truly started. He was sure that the deliberations of the Conference would provide guidelines for activities in the next decade and help to ensure even greater steps forward.

1.4 DRAFTING COMMITTEE

Dr. Brauer informed the Conference that Messrs. S. Blixt, T.T. Chang, K.S. Dodds, E. de Langhe and J.T. Williams had been nominated as a Drafting Committee to collate recommendations made by the Conference. This membership was approved.

2. TECHNICAL SESSIONS

Only authors' summaries of papers presented in each Session are reproduced in this Report together with an account of the discussion that followed. Following the practice of previous technical conferences, it is intended to produce a book based on the proceedings of this one. (See Recommendation 35 below)

2.1 SAMPLING

Session Convenor: Prof. J.G. Hawkes

(i) Capturing the genetic diversity of species — J.G. Hawkes

Crop genetic diversity is disappearing quickly, mainly through the replacement of highly variable landraces and primitive forms by relatively uniform cultivars. Wild relatives of crop plants are also undergoing genetic erosion, though perhaps not as yet on such a disastrous scale. Nevertheless, changes in the natural environment conditioned by the spread of agirculture, destruction of forests, marshes, lakes, scrub and savanna, as well as overgrazing and too intensive agriculture on fragile ecosystems - all these factors are destroying or modifying the natural habitats of wild species, including those that are related to crops.

It is thus obvious that genetic diversity must be stored for present and future plant breeding needs. To do this, correct sampling strategies are essential and should be aimed at capturing maximum genetic diversity within practical limitations of sample size and number.

Although ideally population genetic structure should be analysed for each species before collecting begins, in practice this is impossible. The time needed for such studies would be longer than the threatened populations last, since genetic erosion in many crops is already far advanced. For the present, generalized sampling strategies are being used.

The purpose of this Conference, however, is to evaluate investigations already carried out on certain crops to see whether the techniques are still satisfactory, some eight years since they were proposed in 1973 (Marshall and Brown, 1975, Jain, 1975), and perhaps to propose new techniques and/or refinements to existing ones.

The techniques of sampling procedure stemming from the 1973 FAO/IBP Technical Conference were based on studies with small seeded wild species and some cultivated ones, in which random or non-selective methods were generally agreed to be the most effective; in summary, to sample some 80 seeds from 50-100 random individuals per site, to sample as many sites as possible within the time available, and to ensure that sampling sites represent as broad a range of environments as possible within the target area. How the sites are selected within the total area depends largely on the biological good sense of the collector. Where climatic and soil conditions are relatively uniform spacing of sample sites may be much wider than where there are many rapid changes of environment within a small region. Differences of tribal and/or agricultural customs are also important indicators of possible differences of genetic diversity.

The collection of clonal material of vegetatively propagated crops poses special problems. Here one is not dealing with populations but with the highly reduced and highly selected remnants of populations as well as sub-clonal units with somatic mutations. With these the empirical method is to collect every distinguishable morphotype in each market region, adding randomly sampled seed collections whenever possible. Duplicates can then be eliminated in the genetic resources centre in subsequent years.

When collecting fruit and economic crops whose seeds are of the recalcitrant type the problems of storage are of the greatest importance. Even the preservation of seeds during the expedition poses problems of maintaining viability until they can be sown out in tree nurseries. Budwood cuttings, seedlings and rooted suckers may be more appropriate methods of collecting.

Because in tropical forests the populations are very diffuse (often only 10-20 trees in areas of 100 ha (Whitmore, 1975) the methods for population sampling of annual seed crops cannot be applied here. Agreed sampling and storage methods (meristem banks, seedling banks, etc.) are urgently required.

Seed numbers of very large-seeded species (coconuts being the extreme example) also need to be considered carefully. Perhaps only 10 or 15 seeds of this type are possible for size and weight reasons (Hawkes, 1980), but how much of the allelic diversity can be captured by such methods? We really do not know.

Finally, in devising methods for sampling, attention must always be paid to storage. This applies not only to numbers of seeds but to their storability; and if materials other than seeds are collected, how then should they best be stored? Such considerations will be discussed in future sections.

(ii) Principles of sampling S.K. Jain

Exploration and collection of genetic resources require a series of decisions about the optimal sampling procedures. These require at least four aspects to be considered, namely, (1) determination of priorities based on the status of existing collections and the risk of genetic erosion; (2) nature of biological materials (i.e. wild, weedy, or cultivated, annual and seed-propagated versus asexual perennial form, etc.); (3) collection goals defined in terms of (a) basic population genetic research on variation patterns, (b) a large random

sample of plant materials from different countries and regions for simply storing them away in genebanks, or (c) search for specific genotypes for meeting a breeder's requirements; and (4) practical considerations of local arrangements, travel facilities, political factors, etc.

Accordingly, perhaps "there is no single answer for a sampling strategy... because each species and area has its own problems associated with ecological factors which affect the overall pattern of variation", see IBPGR report on wheat (Croston and Williams, 1980). However, we shall review the recent population studies in wheat, barley, oats, rice, potato, tomato, fruit and forest trees, and other crop genera which now provide fairly large amounts of data on the genetic structure of populations in both wild and cultivated species. Utilizing sampling theory, several alternative strategies will be examined for their effectiveness in collecting allelic and multigenic arrays. The concept of linked gene complexes will be discussed and recommendations for larger samples will be examined theoretically. These models show that the sampling strategies vary significantly with the alternative goals of genetic conservation. Here, again, the need for a joint approach by the evolutionists and breeders should be kept in mind, along with a caveat that biological knowledge of population structure, reproduction, breeding systems , modes of adaptation, ecotypic or clinal variation, and of gene flow between and within species is likely to help our conservation and utilization efforts in the long run.

Several examples of systematic sampling will be presented from our recent work in Amaranthus and Limnanthes. During one of our amaranth collecting missions we attempted to describe population size and subdivision status. This allowed us to test whether different amounts of genetic variability were to be expected in different local stands. Likewise, collections of Limnanthes from wild stands in vernal pools provided a test of the island model of population structure such that taxa with different ranges of distribution had significantly differing levels of variation. Rare and endemic species need to be sampled on a different scale than a widespread colonizing species.

The principles defining an optimal sampling strategy are essentially deductive guidelines to be used primarily in the spirit of developing a statistical and population genetic understanding of the probability arguments, concepts of similarity versus uniqueness of different accessions, and of precautions against the chance losses of genetic variants. It hopefully promotes a scientific attitude towards field work and aids in systematic recording of observations, even when theoretical designs have to be greatly modified due to many pragmatic reasons.

(iii) Sampling techniques for seed crops E. Porceddu

Sampling strategy should ensure preservation of the maximum amount of useful genetic variability whilst keeping the total number of samples within practical limits.

The two principal objectives of germplasm collection are:

1. to supply useful genes to overcome present problems in plant breeding;

2. to conserve gene pools for future breeding requirements.

In both these cases, financial and personnel resources impose restrictions on the number and size of samples to be handled during the various steps involving conservation maintenance and utilization of genetic resources. Collection, evaluation, multiplication and conservation are the main activities of a genebank prior to utilization.

The reason for making the collection and the biology of the different species give each of the activities its own feature. For this reason, different sampling procedures may be required.

The following levels are the minimum requirements for a proper sampling strategy:

Level I	:	sampling of geographical areas and sites within them;
Level II	:	sampling of populations within sites and of plants within populations;
Level III	:	sampling of plants to be multiplied;
Level IV	:	sampling of seeds to be stored;
Level VI	:	sampling of seeds to rejuvenate the stored stock;
Level VII	:	sampling in the collected material for utilization in breeding programmes.

Biological information and statistical methods must both be used to maximize the efficiency of sampling at each level; and new useful information should also be obtained for further improvement. Limiting factors such as time and resources may require elimination of some of the outlined levels but in this case a larger sampling error must be considered with a consequent possible loss of useful genes.

The biological details about the material, e.g. weed relative, wild species, amount of out-crossing, reproductive characteristics, etc., have great importance in sampling from Level II onwards; while at Level I they have secondary influence on the finalization of an optimal sampling strategy. The ecological characteristics and the macro-geographical variability of the area will have a major effect to orientate sampling during preliminary collecting missions, and on the other hand, ecological and genetical aspects of plant communities will be the main concern during sampling second and higher levels.

Statistical theory can help to define the sample properly at each level. The results of a statistical approach, while defining the sample at Levels I and II, will have interpretation on phenetic relationships among plant populations. However, this information is adequate for sampling at levels where factors other than those related to the biology of the species are much more important. From Level III onwards, theory and knowledge of the biology of plant communities should be better developed to integrate the foregoing information in explaining the biological phenomena which regulate the life and survival of the collected plant communities.

(iv) Analysis of variability in cereals and its practical applications to the conservation of genetic resources — P.J. Murphy and J.R. Witcombe

Landraces and introduced cultivars of wheat collected in Northern India were compared when grown in uniform conditions. With the exception of tiller number, no single agronomic character produced marked non-overlapping distributions which would enable local varieties to be clearly distinguished from introduced varieties. However, tiller number is an unreliable character since it has a high phenotypic plasticity.

Multivariate analysis distinguished the introduced and local varieties both on the basis of variety means and of single plant data. Characters not normally included in descriptor lists were important in distinguishing varieties in the multivariate analysis; these included the breadth of the flag leaf and the breadth of the penultimate leaf.

Hence, if multivariate analysis is used, six easily measured characters would distinguish introduced and local varieties. The technique should be satisfactory for plants grown under field conditions if accession means are used in the analysis and this would provide a cost-effective screening to prevent the erroneous inclusion of modern cultivars in genebanks.

Other experiments have confirmed the value of multivariate analysis. For example, the analysis of variation in barley from Tibet, Nepal, India, Pakistan and Afghanistan revealed a large scale geographical pattern of variation. The results of this analysis also showed that there is a fundamental difference between the variation of quantitative characters and qualitative characters. The quantitative characters varied according to region whereas qualitative characters revealed that there is a centre of diversity in Nepal.

The techniques used on wheat and barley are likely to be of use with other crops and could help in collecting and characterization.

(v) Sampling of vegetatively propagated crops — J. León

The sampling procedures developed for seed crops are of limited applicability to non-seed propagated crops. The same is true with the methods used to sample wild populations of vegetatively propagated crops.

Sampling in clonal crops is complicated as this is a heterogeneous group differing in reproductive biology, cultural management and population structure. All those crops, with the exception of a few sterile triploids, produce seed but seed propagation is so erratic or inefficient that they behave as obligate clones. In clonal crops, variation may come mainly from bud mutation (a factor of primary importance in their evolution) and segregation provides occasional new material. In both cases survival depends on human action.

Up to now, sampling procedures have been limited to a purposive approach. This is understandable, because on one hand the application of random or systematic sampling in a large clonal population is almost a futile exercise and, on the other hand, there is a need to cover every possible variant in the limited populations of primitive clonal crops.

If all crops are artifacts, clonally propagated crops are even more completely tied to man for their reproduction and survival. This is an important consideration in sampling, because population size, distribution and frequency depend on human activities. In a plantation crop, monoclonal stands are the rule. Therefore bud mutants may be the only materials worth collecting as they are usually rogued out. Controlled sampling in such stands could lead to missing variants.

A different situation may occur when populations are small and heterogeneous. In this case stratification may help considerably, in the first place by separating agricultural areas; in the second (and perhaps more important) by delimiting ethnic groups, based on cultural characteristics such as language, types of houses, racial composition and others. Once this stage is reached, the proper sampling design: systematic, unaligned or other, could be chosen, depending on the accuracy required, costs, manpower available and other logistic considerations. It is very likely that in these cases a transect method may appear more desirable than quadrats.

The type of sample varies with the species. In most cases, vegetative materials (cuttings, corms or other propagules) are short-lived and require careful preparation, handling and transportation. Quantity is less important in the samples.

As a phenotypic approach to the selection of samples is followed by all collectors, it should be remembered that quite often characteristics such as resistance, earliness and others are found in individuals which do not show any distinctive phenotypic character. At the cost of redundance in established collections the sampling, purposive or otherwise, of as many variants as possible, is preferable to the loss of valuable materials.

(vii) Discussion

JAIN'S paper: FRANKEL said that evolutionary studies are essential although they will not be feasible for all crops. Random sampling was absolutely necessary to preserve existing variation as fully as possible. The use of existing collections for evolutionary studies might have the drawback of incomplete representation and therefore studies should be carried out very carefully.

MURPHY'S and WITCOMBE'S paper: GROBMAN felt that visual observations by someone with experience of the crop were just as useful as multivariate analyses of quantitative measurements and were quicker. FRANKEL suggested the use of alloenzymes instead of quantitative characters. In reply MURPHY said that the difference between naked and covered barley was recognized by multivariate analysis but not by alloenzyme analysis; certainly the latter could be a supplementary method. FEISTRITZER asked where locally bred cultivars would fit in. MURPHY: That is what I would like to know. MEHRA said that in India the results of multivariate analyses were not consistent in different environments and regions and these factors must be taken into account.

LEON'S paper: HAWKES referred to his Manual for Collectors published by IBPGR/EUCARPIA; what did Léon think of it as regards vegetatively propagated crops? LEON: Extremely useful. We should go further by giving collectors information on how to sample to be sure of getting representative variability from a given area. HUAMAN commented that the best way to sample potato cultivars is by gathering diverse types in a field being harvested. GIACOMETTI: For collecting germplasm of rubber trees we used both selective and random sampling. Budwood was taken from high yielding trees noted by latex collectors and seeds at random. SIGURBJORNSSON asked whether mutations should be preserved when they can be produced at will by mutagens. Both LEON and HAWKES said they should be kept.

General: MEHRA was of the opinion that studies of genetic variability and distribution were often based on limited material in collections. Conclusions could be misleading. Sampling at random from areas with high genetic diversity was a much more useful approach. HAWKES: It is therefore essential that passport information should always accompany samples. PORCEDDU did not agree with MEHRA. Many studies used large numbers of samples, for example JAIN had used 3,000 durum wheats, 1,700 barley samples, 600 cotton, 700 faba beans and 600 finger millets. GROBMAN thought it was unfortunate that the term germplasm to include advanced cultivars was being used as a synonym of the term genetic resources. A large number of population samples are kept by research institutes and private breeders and these should be deposited in gene banks. It was much more important to store landraces than advanced cultivars. FRANKEL asked by HAWKES to define genetic resources, said that they embraced wild relatives, landraces, primitive and advanced cultivars and genetic stocks. FRANKEL referred to an investigation of alloenzyme variation in 12 landraces of wheat from Iran. He expressed the view that alloenzymes are better markers for variation than morphological characters. WITCOMBE considered phenotypic characterization as most important. JAIN said that a combination of phenotypic characterization and isoenzyme techniques should be applied to assess variability. CHANG observed that it is very useful to use information provided by farmers and extension workers. ESQUINAS once more stressed the importance of isoenzyme techniques to assess variability. MURPHY said that he proposed to apply multivariate analysis techniques to data provided by isoenzyme techniques. MEHRA said that in training courses in India students tested three types of sampling: stratified, random and from the edges of the field. In most cases stratified sampling proved to be the best method.

2.2 CONSERVATION I

Session Convenor: Prof. R.J. Olembo

(i) Introductory remarks R.J. Olembo

The essence of genetic resources conservation

It is a tautology to have to state that conservation is the main business of genetic resources work. Lest it be forgotten, let it be repeated. Unless the results and fruits of hard labour spent in surveying, exploring, collecting, documenting and indeed evaluating end up in storing genetic diversity for rainy days, then the labour has been in vain. It is to the credit of the Conference Organizers that fully three sessions are devoted to conservation, and these sessions should provide plenty of time and opportunity to critically explore

recent advances in attempts at the preservation of all types of plant material considered worthy of conserving for the needs of present-day practitioners of plant production and those of the future - including, I dare say, the genetic engineers!

The well-worked situation relates to genetic conservation of crop plants. Diverse methods are universally recognized: seed storage; plants maintained as seedlings and clonally propagated plants where storage by seed is impossible because of genetic and physiological considerations. Professor E.H. Roberts and his team at Reading University have worked on seed storage for a number of years and this session is in their debt for preparing the three papers before us. We should be reminded of the purposes of conservation: simply stated that the assembled material must be available for utilization, regeneration or for viability testing as it was genetically when entered in the collection; or, using the well-known technical terminology, since it cannot be avoided altogether, erosion must be minimized. So whether we agree on the description of the material we are about to preserve or not - and this matter of terminology has recently been taken up by Professor Simmonds who dislikes the word "recalcitrant" in connection with plants which provide seeds which cannot be stored dry and in cold storage - our purposes in establishing a genebank for any particular crop must be clear and should be met. In the first paper Roberts and Ellis consider viability and integrity of genetic resources in the context of seeds stored in specified conditions, while in the second paper the vitally important matter of regeneration, which raises a whole set of policy considerations, is examined and some guidance is given. In the final paper of Part 1, Roberts and King return to the "recalcitrant" problems. The question that remains relates to crops like sugarcane and coffee which may be amenable to conservation on an 'opportunity-basis', if I might add to the jargon, but I suppose those who work on these and other species have to write their own papers!

(ii) <u>The prediction of seed deterioration during storage</u> — E.H. Roberts and R.H. Ellis

Since the last Technical Conference in Rome, the IBPGR has recommended preferred storage conditions for the long-term conservation of orthodox seeds. Essentially it is suggested that seeds should be dried to 5 ± 1% moisture content, placed in sealed containers and stored at -18°C or less. Since those recommendations were made our understanding of the quantitative relationships between storage environment and seed deterioration has improved, and estimates of the expected longevity of many major crop species under a wide variety of storage conditions are being obtained. The results confirm the suitability of the IBPGR recommendations and also provide a basis for planning and managing seed banks.

Within a single, genetically homegeneous population stored under a stable environment, the lifespans of the individual seeds differ considerably. The frequency of deaths per unit time conform to the normal distribution. The slope of the seed survival curve (a negative cumulative normal distribution) is a measure of the seed-to-seed variation in lifespan and is a function of the reciprocal of the standard deviation of the frequency distribution. The standard deviation is increased in better storage conditions (lower temperatures and/or moisture contents) since the lifespan of each seed is increased by the same proportion.

Under the same storage conditions, the slopes of the survival curves for different accessions of a species are identical and can be related mathematically to temperature and moisture content. Although the slopes of their survival curves are the same under identical storage conditions, different accessions may differ considerably in the time taken to fall to a given level of viability since the survival curves may be displaced in time as a result of differences in genotype and pre-storage experience. These differances between accessions can be described by a single constant which estimates how far the accession has already deteriorated when it is received. It is a function of the combined effects of genotype, pre-storage environment and their interaction and indicates the viability status of the accession in units of the standard deviation above 50% viability. Thus it also indicates in terms of these units, how far the accession has to decline before it reaches any other level of viability.

Consequently, although the rate of ageing in all seeds in all accessions is identical under the same storage conditions, the change in percentage viability over any given storage period differs between accessions. This is because the survival curves are not linear and accessions differ in the extent to which they have deteriorated before storage. However it is now possible to estimate this pre-storage deterioration for each accession and estimate subsequent rate of loss of viability under any given set of storage conditions. Thus it is possible to estimate how long it will be for any accession to fall to the particular percentage viability (the regeneration standard) when it has been decided that it would be appropriate for the accession to be regenerated (grown to supply fresh seeds for further storage).

Although there is still some controversy, we believe that the evidence shows that loss of viability is always accompanied by the accumulation of considerable mutation, increasing towards an asymptote in the surviving seeds as viability falls towards about 50%. Furthermore loss of viability in genetically heterogeneous accessions will inevitably lead to selection of longer lived genotypes. Consequently, the regeneration standard should be set, within the bounds of practical convenience, at a high level of viability.

The estimate of regeneration interval provides a rational basis upon which to predetermine the time to elapse before testing the viability of accessions during storage (the monitoring interval) which, to allow for error, should be shorter than but related to, the estimated regeneration interval. These estimates are important in order to avoid unnecessary genetic changes or the complete loss of an accession which could result from monitoring too infrequently.

(iii) Procedures for monitoring accessions during seed storage — R.H. Ellis and E.H. Roberts

Even under good long-term storage conditions as, for example, those recommended by IBPGR, gradual loss of seed viability will occur during storage and it will be necessary to monitor accessions using destructive germination tests to determine when regeneration is required. The regeneration procedure is difficult, risky and expensive; consequently the probability of deciding to regenerate an accession when it is unnecessary should be minimized. The monitoring tests themselves will also be expensive in use of resources and in the depletion of the numbers of

seeds within accessions, particularly since the costs and difficulties of collecting samples will often severely limit the number of genes which constitute an accession.

Three possible fates await the viable seeds within an accession: utilization in breeding programmes, regeneration to replace the accession with fresh seed stocks, or germination to test viability in monitoring tests. Past experience has indicated that it is the use of seeds in monitoring tests which is often the major source of depletion. The number of seeds required for this purpose will be the product of the number of monitoring tests before regeneration is called for, and the number of seeds in each monitoring test.

The more frequently accessions are monitored for viability the greater will be the costs of maintaining the store, the more rapid the decline in seed numbers resulting in unnecessarily early regeneration of accessions, and the greater the cumulative probability of regenerating accessions in error. Thus the monitoring interval should be as long as possible, but not so long as to run the risk of viability falling below the regeneration standard which would carry with it the risk of genetic change or, in the extreme case, the loss of an accession through complete loss of viability. The viability equations developed to predict seed longevity provide a rational basis for determining the monitoring interval for each accession.

The number of seeds in each monitoring test and the percentage viability of the accession will influence the accuracy of the test result and therefore the error probability attached to the consequent decision as to whether it is time to regenerate. The fixed sample-size test normally adopted at present needs to contain sufficient seeds to cater for the poorest result to be expected.

Seed bank management includes a series of decision-making procedures. The combination of predetermined monitoring intervals for each accession and sequential germination tests would provide an integrated, economic and safe system for monitoring both genetically homogeneous and heterogeneous accessions, and would provide an economic and safe system for monitoring the viability of accessions and deciding when to regenerate. For genebanks the poorest result expected is the regeneration standard, and thus at higher viabilities more seeds are used than necessary. In contrast the adoption of a sequential germination test procedure would enable the number of seeds tested to vary with the result obtained. Both fixed sample-size and sequential germination tests will detect whether the viability of an accession has fallen to a prescribed level for regeneration (the regeneration standard) with given probabilities of error, but the sequential test will use far less seed in doing so.

In genetically homogeneous accessions, to avoid unnecessary genetic mutations which are associated with loss of viability, the regeneration standard should be set at a relatively high level of viability. In the case of genetically heterogeneous accessions the same argument applies but there are further compelling reasons for maintaining a high regeneration standard. Since there is genotypic variation in seed longevity, loss of viability during storage will tend to delete some genetic components from the population. Even if not deleted during storage, those components of the accession which have lost more viability will show considerably reduced

physiological seed vigour and be more vulnerable to stress in the regeneration environment. Then if they survive the regeneration procedure their originally lower level of seed viability will mean that the progeny contain more mutation than is typical for the accession as a whole.

(iv) Problems of storing recalcitrant seed during collection and conservation — E.H. Roberts and M.W. King

Recalcitrant seeds are those which cannot be dried below some relatively high moisture content without causing damage which results in rapid loss of viability. Even under moist storage conditions they are relatively short-lived and last no more than a few weeks or a few months, depending on the species. Some orthodox seeds are also short-lived under ambient conditions, but all orthodox seeds can be dried to 5% moisture content or less and dry, low-temperature storage provides a practical system for long-term conservation. Furthermore many orthodox seeds can be stored for several years or decades in a fully imbibed condition (providing germination can be prevented) - i.e., longer than most recalcitrant seeds. Consequently it is clear that recalcitrant seeds have a physiologically distinct behaviour from orthodox seeds. The definition of recalcitrant seeds rests mainly on their inability to withstand desiccation and their short-lived characteristics even when fully imbibed.

Recalcitrant seeds are not uncommon in those woody perennials which produce large and fleshy seeds, and it is these plants which are of interest from the point of view of genetic conservation. They include such economically important species as cocoa, rubber, tea, most of the tropical fruits and many timber species. However, not all large seeds of woody species are recalcitrant. For example, it was originally thought that Citrus species are recalcitrant, but recent work has shown that several species can be dried to 5% moisture content and are essentially orthodox. However, once dried, the seeds take a long time to rehydrate when placed in a germination medium and are therefore slow to germinate and can easily be mistaken as being non-viable. But once this problem is recognized dry storage at low temperature is feasible. A similar problem has now been recognized in the tropical timber species Azadiraenta indica and such behaviour is suspected in a number of other species. Another problem which has previously led to mistaken classification is that some seeds are difficult to dry so that when using ordinary techniques the seeds tend to lose viability during the drying process since they remain too long at temperatures and moisture contents which are very deleterious to all orthodox seeds. This apparently is the case with another timber species, Agathis macrophylla which, although relatively short-lived, shows essentially orthodox characteristics.

These examples show that the recognition of orthodox behaviour is not always simple, but is an important preliminary to deciding whether long-term seed storage is feasible using current technology. Little progress has been made in the storage of truly recalcitrant seeds except for small improvements resulting from minor modifications to existing techniques. In most cases the best recorded methods involve storage in a fully, or almost fully, imbibed condition in a moist medium under aerobic conditions (e.g. in a thin polythene bag not tightly sealed) where the seed has received a preliminary treatment with hot water or a fungicide to inhibit microbial growth. One of the common problems is that imbibed seeds tend to germinate during storage. In some cases cool conditions help, but many tropical

seeds are susceptible to chilling injury, e.g. cocoa at 10° C and below. Chemical or osmotic inhibition of germination has not yet been successful for more than short periods. No doubt, further improvements in conventional techniques will be possible and, even if minor, should not be ignored since they may ease the problem of field collecting. However, conventional wet seed storage techniques do not hold much promise for the genetic conservation of material for, to be of any value for this purpose, the period of seed longevity in storage should be at least as long as the minimum life-cycle of the plant from sowing to first harvest, which may be several years of decades.

There has been considerable speculation, therefore, as to other possible approaches to the long-term storage of recalcitrant seeds. One possibility is cryogenic storage by adapting techniques that have been used successfully particularly for animal tissues provided freezing injury can be avoided. Recalcitrant seeds pose special problems some of which relate to size and it is by no means clear whether these can be overcome. If they cannot then the conservation of recalcitrant species will have to depend on existing technology, e.g. the use of living collections or pollen storage, or the development of alternative ones such as the use of tissue or meritstem cultures.

(v) Discussion

On being invited to open the discussion, SIMMONDS said that the last two or three years had seen improvements in seed storage but useful work on short-lived seeds had been done only in the last year or so. Our knowledge was still rudimentary. It emerges that there are far fewer short-lived seeds than supposed. We are unlikely to find eventually that all short-lived seeds can be stored. What to do about the residue? Perhaps discussion could be developed in the context of clonal material. For example, Cacao could possibly be handled as a collection of clones by culture techniques though meristem cultures of woody plants present problems. SIMMONDS wished to substitute the term 'short-lived' for 'recalcitrant' which ROBERTS defended. GIACOMETTI said that in Brazil recalcitrant seeds packed under wet conditions were often rotten on arrival. When treated with fungicide before despatch and packed in charcoal, they would store for about a month. STANWOOD asked ROBERTS to define parameters for recalcitrant seeds. He had found at Fort Collins, that if loss of electrolytes was monitored, there was an increase in the amount of leachates in recalcitrant seeds. Had ROBERTS looked at other parameters that may help in identifying recalcitrant seeds? ROBERTS said that electrolyte leakage does occur from orthodox seds in poor condition, it being a symptom of membrane damage. He had not done any work specifically to identify one type or the other. He wished to stress the point that it is not always easy to decide that a seed is damaged by drying as other factors can be misleading. ELLIS remarked that one of the reasons for using the term recalcitrant for the drying phenomenon is that so many phenomena seen in recalcitrant seeds in the imbibed state occur in orthodox seeds at similar moisture contents; for example, electrolyte leakage. It was not a useful character for distinguishing the two types. SORIA said one of the main objectives of work on recalcitrant seeds was to lengthen the period for interchange of germplasm. Recalcitrant seeds could not be conserved. In plants such as Cacao the maintenance of clones was too expensive and difficult to be a method for storing genetic diversity. Could clones be supplemented by pollen preservation? ROBERTS said pollen raised some

of the same sorts of problems as seeds. The life of most pollens can be extended by drying and cooling but not the remainder. Pollen and seed behaviour were not correlated. ABIFARIN asked ROBERTS if his mention of the possibility of keeping orthodox seed viable for a long time after it is imbibed meant before doemancy is broken. And how was the problem of storing wet seeds to be solved? ROBERTS said wet seeds could only be stored if they could be kept dormant. This is difficult for seeds of many cultivars and wild species. Hormone inhibitors only work for a short time. If concentrations of osmotica are used to prevent water uptake, e.g. polyethylene glycol, this is equivalent to drying and shortens longevity. Wet storage of orthodox seeds holds no promise for long-term genetic conservation. WILLIAMS and HANSON pointed out that the regeneration of orthodox seeds is expensive, fraught with problems not least probable genetic change. For seeds with high percentage viability when stored should the standard for regeneration, i.e. a 5 percent drop in viability, be revised? ROBERTS: The old definition, regeneration after a significant loss of viability, turns out not to be a good one as it gives a sliding scale for regeneration and the statistics for the tests are questionable. It is better to have a fixed standard; for the majority of species, probably 85 percent viability. A high viability standard is required to minimize genetic change either by selection or mutation. Using IBPGR preferred storage conditions (-20°C and 5-7% moisture content) generation intervals may be a century or more; even for vegetable seeds it is a matter of decades. Regeneration therefore becomes an infrequent operation. ELLIS observed that for genebanks with storage under preferred conditions, the biggest problems caused by the long time scale concerned germination tests and decision making. MUMFORD said she would like to see more categories included in recalcitrant seeds. Citrus seeds in general tolerate desiccation and low temperature but there were differences betwe a species in behaviour and also for storage life. Although they were not classified as orthodox, there was room for clarification. A distinction should be made between recalcitrant seeds that tolerate low temperature and desiccation and those like seeds of Cacao that are very sensitive to low temperature. Could dormant phases in the growth cycle of a plant other than seeds be exploited for long-term storage? ROBERTS was not convinced of the need to extend terminology. Some species had dormant seedlings and of course buds were dormant but for most species these were not promising materials for storage. ELLIS observed that with moisture contents of 20 percent and above, the effect of temperature on longevity could lead to data being misinterpreted. This moisture range is outside that used for seed storage.

2.3 CONSERVATION II

Session Convenor: Prof. E.H. Roberts

(i) The importance of in vitro techniques in germplasm conservation

E. de Langhe

For a large number of crops grown under tropical or subtropical conditions, germplasm conservation by seed storage is, for various reasons, very difficult, sometimes impossible and sometimes irrelevant.

The different categories of crops that are usually propagated asexually are: selected heterozygotes, crops with non viable or so-called "recalcitrant" seeds, crops with a very low seed production capacity, crops with sterile generative tissues and crops with an excessively long juvenile phase. Some crops belong to more than one of these categories (see Tables 1 and 2).

TABLE 1

Crops, by tradition, clonally propagated

(vide Hartmann & Kester, 1975; Purseglove, 1972)

FOOD	FIBRE
Arrowroot	Abaca (Manila hemp)
Breadfruit	Henequen, Mauritius hemp, Sisal
Cassava	Kapok
Cocoyam, Dasheen, Taro (Eddoe)	Ramie
Edible canna	
Plantain and other cooking banana cvs.	
Sweet potato	
Yam	
FRUIT	**SPICES/FLAVOURINGS**
Currant	Vanilla
Date palm	Arecanut
Dessert bananas	Cardamon
Fig	Garlic
Kiwi	Ginger
Litchi	Pepper
Olive	Turmeric
Pomegranate	**VARIOUS**
Pineapple	Sugarcane

TABLE 2

Seed propagated crops; asexual propagation increasingly important
(Vide, Hartmann & Kester, 1975; Purseglove, 1972)

	FRUITS AND NUTS		OILSEEDS
	Annona		Castor (annual herbs common)
R	Avocado	R	Tung
	Carambola		SPICES AND CONDIMENTS
	Cashew		
R	*Citrus* spp.		Clove
R	*Cola* spp.	R	Cinnamon
R	Durian		Nutmeg
	Feijoa (Chinese date)		Pimento
	Giant grenadilla		Rosselle
	Guava		VARIOUS
R	Jackfruit	R	*Cacao*
	Indian jujube	R	*Coffea* spp. (*C. canephora*, *C. liberica*)
R	Macademia nut	R	*Hevea brasiliensis*
R	Mango	R	Tea
R	Mangosteen		*Cinchona*
R	Rambutan		
	Tamarind		

R = with recalcitrant seeds (King & Roberts, 1979)

For each category an example was given to explain the related technical or economic problems. Attention is drawn to the conceptual difference between genepool conservation and genotype conservation, and the implications of this difference for the plants invol ed. In this respect there is the possibility of in situ conservation but this alternative is feasible only under rather highly controlled growth conditions.

For most of the plants under consideration, in vitro conservation of plant tissues under aseptic conditions would appear to present the safest method for germplasm conservation. This concept needs to be developed within the framework of international, regional or national genebank and the exchange of disease-free material.

A brief explanation was given of in vitro culture techniques and of tissues appropriate for culture initiation. Requiring special attention are the present possibilities for in vitro manipulation of tissues, the necessity for and frequency of tissue transplantation and the stability of genotypes in vitro.

The organization of an international network of in vitro germplasm storage facilities will not exclude the need for a parallel development in the field (but on a moderate scale) of the corresponding genotypes.

(ii) Genetic stability in in vitro cultures G.G. Henshaw

There is a widespread belief that genetic instability is a characteristic feature of in vitro cultures. It might appear, therefore, that such systems would be quite unsuitable for genetic conservation, and yet it is also well-known that in vitro techniques are now being used successfully in the horticultural industry for propagation. This apparent contradiction is a consequence of the diversity of in vitro systems, the range including, on the one hand, organized cultures which can virtually be complete plants and, on the other hand, disorganized cultures which may consist of isolated cells or even protoplasts. The diversity is such that generalizations about the stability of in vitro systems is generally misleading.

The most useful generalization, which again is only partially true, is that the organized cultures are more stable, genetically, than the disorganized cultures. The former include shoot tip cultures, derived from the indeterminate shoot apical mersitems, and their apparent genetic stability seems to reflect the inherent stability of such meristems which would normally constitute what is essentially the germline of the plant. A large proportion of the successful in vitro propagation systems are based on this type of culture and the evidence of stability for many species is good. There is, however, ample evidence, based largely on chromosome studies, of genetic instability in disorganized cultures which include callus, suspension and cell cultures. A further problem with such cultures is that their plant-regeneration capacity is frequently an unstable property which may or may not be related to their genetic instability. Nevertheless, there are some disorganized cultures which do not conform to these "rules" and with certain species satisfactory propagation procedures employing callus cultures have been described.

One of the major problems affecting an assessment of the genetic stability of in vitro systems is the largely unsatisfactory nature of the genetic evidence. Some of the cytological evidence showing gross chromosome abnormalities is quite unequivocal, but information concerning the frequency of point mutations is very limited, since it demands the type of genetic analysis which has rarely been applied with in vitro studies. Further, there are many reported observations of in vitro systems producing "variants", the genetic status of which is quite obscure. It is most important that there should be a thorough genetic analysis of such variants with a suitable model species, not only because of the implications for genetic conservation but also because of the possibility of their exploitation for plant breeding purposes if they are shown to have a genetic basis.

The causes of genetic instability in particular cultures are poorly understood, but they may be ascribed to some combination of three important factors: the possibility of variation among the cells of the original explant - since the somatic tissues of many plant species are known to be mixoploid - compounded by the selective and mutagenic effects of the in vitro conditions. The evidence suggests that the prospects for improving the stability of certain cultures are not good, at least when they are maintained in a growing state. Care can be taken with the choice of explant and also the use of certain growth regulators suspected of having mutagenic properties may be avoided, but by far the most important consideration is the correct choice of culture system which, generally speaking, will be of the organized type. If this approach does not produce a satisfactory level of stability, some means of suspending growth, such as cryogenic storage, would at present seem to be the only practical alternative.

(iii) Germplasm conservation in vitro: present state of research and importance of cryopreservation — Lyndsey A. Withers

In vitro culture methods can be used to carry out rapid clonal propagation of certain plants, to facilitate the international exchange of germplasm, and to store germplasm for extended periods of time. Two possible approaches may be taken to storage: (1) the use of growth limitation by the maintenance of cultures on modified media or at a reduced temperature or a combination of both; or (2) cryopreservation, i.e. storage in liquid nitrogen.

The technology of cryopreservation is relatively simple but it is important to use a freeze-thaw protocol appropriate to the *in vitro* system in question. Once in storage, cryopreservation cultures are very stable and large numbers can be stored in a relatively small space with the minimum of attention required during the storage period.

In order to obtain a clear picture of the present state of development of *in vitro* methodology relevant to germplasm conservation, the IBPGR has supported a survey of on-going research to learn about progress and problems. Thus during recent months, a questionnaire has been sent to over 300 individuals and institutions in 68 countries asking for particulars about aspects of culture initiation, plant regeneration and storage and exchange of cultures of 32 chosen genera and species. The response has been very encouraging: approximately 50% of those contacted replied, and in all, over 250 completed questionnaires have been returned. The findings of this survey have been evaluated in a report (IBPGR, 1981). They lead to the following conclusions.

It appears that although many genera and species are receiving a substantial amount of attention directed towards their propagation *in vitro*, many others are not. However, whilst some failures can be attributed to an insufficient input of effort, in other cases it would seem that persistent problems in the maintenance of cultures and the induction of morphogenesis are responsible. Solutions to such problems may be expedited by appropriate biochemical studies. Operational problems are encountered by some workers, those in developing countries generally reporting a shortage of equipment or experienced personnel, and those in developed countries, difficulties in obtaining suitable plant material.

Only rarely is the routine cytological examination of cultures and plants carried out in order to monitor genetic stability. Although this may reflect some lack of expertise, it must be concluded that such procedures are given a low priority by many workers. Nonetheless, the common experience that there is a close phenotypic resemblance between parental and regenerant plants is encouraging.

Very few of the reports in the literature describing the successful cryopreservation of cultures relate to species of interest here. The survey confirms that activity is still at a very low level and, further, that no-one is yet using cryopreservation for the long-term storage of valuable germplasm on a routine basis. Clearly much developmental work remains to be done. However, many workers do appear to be using growth limitation techniques. Success is varied, some workers reporting high viabilities after substantial storage periods, others reporting serious difficulties including an unacceptable loss of viability, loss of totipotency and microbial con-

tamination. There is no lack of interest in this area, but it does seem that attempts to carry out storage are incidental to other studies and are less than comprehensive.

Procedures for the international exchange of germplasm using standard postal and freight services are well established for a limited number of species. Few insuperable problems of a biological or operational nature are encountered and it is likely that the procedures could be adopted more widely. However, the international exchange of frozen material had yet to be attempted.

Finally, two general observations can be made: (i) In a number of areas of methodology and for a number of species, an initiative may be required to stimulate appropriate research activity; and (ii) there is a certain amount of pertinent information which, for various reasons, remains unreported in the literature. If made more widely accessible, it would aid progress in the development and adoption of in vitro techniques in plant genetic conservation and aid the efficient direction of effort and resources in this important field.

(iv) Discussion

CARDENAS-RAMOS reported that his colleagues had cultured Agave spp. in vitro. Had WITHERS looked at cryopreservation of whole seeds? WITHERS: not herself but others had done so successfully. Failures were usually due to the gross size of seeds as with large pieces of tissue. PERNES thought a distinction should be made between two types of plants: those whose cultures simulate normal plant propagation and those quite different from normal reproduction systems. In the latter considerable change can arise and organized tissue may not regenerate a normal plant e.g. in grape the vegetative vigour is increased but flowering does not occur; pineapple showed morphological changes; potato tuber size did not return to normal until several generations had been grown. Unorganized tissue (protoplast, cell suspensions, callus and pollen) may be DNA stable but unable to develop into a normal plant. In normal reproduction by seeds, two systems connected with meiosis come into play for repairs and correction. When there is no meiosis, mutations occur some of which may be changes in DNA. The changes that occur by transposition of repetitive elements of DNA are very different from those caused by mutagens. These anomalies can only be seen in plant progeny. HENSHAW agreed there were organized and disorganized cultures and the former are very much more genetically stable than the latter. Genetic changes may occur at the chromosomal level or to genes. More information is needed about genetic changes in tissues grown by in vitro methods. We do not know whether the changes described in grape and pineapple are physiological or genetic. As regards potato, first generation tubers would not be expected to be full sized. WITHERS agreed stable cultures were needed for conservation but the great potential of unstable cultures for production of variants should not be overlooked. AMARAU asked whether we could now recommend the replacement of traditional in situ methods of conservation by in vitro methods or was more research required. WITHERS said both traditional and in vitro methods must be used concurrently. FRANKEL asked one of the speakers to comment on soma clones; the remarkable finding of new kinds of plants that arise in tissue cultures; in potato yield increases of 40-70 percent and remarkable changes in sugarcane. HENSHAW did not refer to these phenomena because we have no explanation. Protoplasts had been isolated notably from potato by Shepherd and used to produce protoclones; he now thinks the variants may be the result of the technique used to develop the protoclones. SIMMONDS said the clear message from the discussion was that meristem or stem-tip culture was

the most important technique at present. Numbers of plants that could be handled this way had increased rapidly but woody plants were a problem. Would be experts care to offer any comments about these refractory plants? DE LANGHE said tissue blackening caused by the polyphenol oxidase systems could be a major problem in the in vitro propagation of both woody and herbaceous plants; cells were killed before they could divide. More basic biochemical research was needed. HENSHAW agreed the difference between woody and herbaceous tissue was very important; it was surprising how little work had been done with stem-tip culture in the former. The phase change certainly caused real problems. It was easier to derive a culture from a juvenile plant but this type of culture might not suit the conservationist. HARLAN commented that if it is true as PERNES suggests that genetic changes in vitro are due to mobile repetitive DNAs, this could be analysed without sexual propagation in Russet Burbank. It would be an exciting area in the breeding and development of new plants.

2.4 CONSERVATION III

Session Convenor: H. Garrison Wilkes

(i) In situ conservation of genetic resources

R. Prescott-Allen

Several conferences and experts on crop genetic resources have called for the in situ conservation of crop gene pools yet very little has been done. This Conference should re-emphasize the need for such conservation and propose a set of actions to achieve it.

Wild species already play a significant role in the improvement of several crops and their importance for plant breeding is expected to grow. They have helped to increase yields, improve quality, widen adaptation, add vigour, provide new modes of reproduction and cytoplasms, facilitate crossing, confer a number of other desirable characters, and above all to provide resistance to a great many diseases and pests.

This important resource is threatened increasingly, however, by habitat alteration and removal and by over-exploration. To ensure the continued availability of the resource it must be conserved, both in situ, in protected areas, and ex situ, in gene banks. In situ conservation should be the chief means because, although protected areas may be vulnerable to external pressures, they do not have some of the disadvantages of gene banks and have certain advantages of their own. However, neither in situ nor ex situ conservation is likely to be wholly successful without sound planning, allocation and management of land uses.

If protected areas are to realize their potential for the in situ conservation of crop genetic resources, they should be designed, distributed and managed to maintain as many genotypes of the wild relatives as possible. They should also provide data on the species they maintain, allow the collection of germplasm, and have efficient links with facilities for research and standby storage. Special areas may be needed to protect associations of crop, weed and wild species of educational, scientific and cultural importance.

A preliminary review of the status of the wild relatives of crops and a survey of government agencies responsible for protected areas have been made in a sample of 50 countries. Eight taxa are known to be endangered, 12 vulnerable, and 7 rare. Several others are suspected to be threatened, and many more - particularly species that are narrowly endemic or patchily distributed - are likely to be. Most of the taxa known to be threatened or rare are not in a protected area. Information on the

representation in protected areas of other wild relatives of crops is deficient. Few protected areas maintain adequate data on the crop genetic resources they may maintain, and few provide potential users with ready access to those resources or have adequate links with research and storage facilities.

Action is needed to protect those species known to be threatened or rare, to improve the usefulness of protected areas for the conservation of crop genetic resources, to provide information essential for the conservation of the wild relatives of crops, and to develop functional links between users of crop genetic resources and those concerned with their in situ conservation.

(ii) Use of a back-garden system and natural reserves for iso-climatic regeneration of germplasm in Hungary — L. Holly

Collection of landraces and ecotypes still existing receive major attention in the work at Tápiószele. An increasing number of samples have been collected during the last few years - mostly vegetables and grain legumes - but a number of local maize populations, clover and grass ecotypes have also been collected.

In parallel with the increase of collecting activity, an urgent need arose for the rejuvenation of Hungarian landraces collected in earlier years. Therefore, a "back-garden system" has been considerably improved and extended and it now includes 87 contributors. The system is subdivided into nine districts, directed by district supervisors who are usually retired research workers or teachers. Four of the districts are in the Transdanubian area, four others in the Hungarian Great Plain, and another includes the villages around Tápiószele. Using this network, we are now able to rejuvenate or multiply some 500-600 accessions each year. This capacity seems to be sufficient for the systematic regeneration of Hungarian germplasm material.

During the last decade, three National Parks were established in Hungary: Hortobágy, Kiskunság and Bükk. One of their important tasks is to preserve plant genetic resources existing in their territories. Our Research Centre collaborates with all these Parks but from the germplasm preservation and regeneration aspects the National park Kiskunság has the highest interest. Some 600 farmsteads still exist in the territory of this National Park, and some of them are included in the Park's long-term plans for preservation of former farming facilities and techniques. These places also provide a unique possibility for germplasm regeneration, because they are well isolated from each other spatially, and chemical treatments (e.g. application of fertilizersm pesticides), are strictly regulated even on the surrounding so called buffer areas. These natural reserves can serve two main purposes:

(a) to rejuvenate and multiply landraces and old improved varieties, landrace selections which originated in similar ecological conditions; and

(b) to conduct experiments to compare the effects of dynamic and static preservation techniques on the genetic structure of certain variable crop populations.

We have only had three years' experience in collaborating with National parks and other natural reserves but it seems very clear that they can provide us with the kind of extreme crop habitats which are quickly disappearing in lands cultivated by modern techniques. National Parks can therefore help us to introduce a higher degree of ecological diversity into our germplasm regeneration system, and it might result in a more successful maintenance of genetic diversity in our landrace collections.

(iii) General principles of germplasm regeneration O. Frankel

The genetic integrity of a population sample has to be maintained despite the risks attending cultivation for the purpose of regeneration or multiplication of accessions in germplasm collections. In fact the two operations are identical and often are combined.

To maintain the population genetic structure during regeneration, three requirements must be met. First, the breeding system must be controlled. This involves the prevention of outcrossing with other accessions. Further, in cross-fertilized species fertilization within entries needs to be controlled, whether by isolation of the entry, with aids for cross-fertilization if required, or by controlled crossing within the entry. The procedures adopted will depend on the species, available facilities, etc. They present problems familiar to breeders of the same and similar species.

The second requirement is to prevent or reduce natural selection in an environment other than the one from which the accession derives. Hence it is often claimed that regeneration should take place in the locality in which the entry has evolved. This is not only difficult and expensive, as is generally recognized, but often impracticable. Indeed it is altogether unnecessary; provided that survival is maximized, i.e. if all or most of the components of a population survive and reproduce. Clearly if this is the case and if roughly equal amounts of seed are harvested from each component, allele frequencies remain more or less the same.

How can this be achieved, in the face of obvious difficulties? Let us consider the difficulties. First, there is climatic incompatibility which may cause the loss of entire entries, or drastic selection among components of populations. Length of day, vernalization requirement, critical temperatures at the regeneration site must be within the tolerance range of the material to be grown. It is necessary to choose the site (or sites) in relation to the requirements of a species, or a section of a species.

Cultivation, water supply and strict control of diseases and pests are further essentials for preventing losses during the growing season and plants should be placed sufficiently widely to reduce inter-plant competition.

The third requirement is for avoidance of genetic drift in small populations. This is not likely to be a serious threat, since the combined requirements for the conservation and utilization streams would be such as to obviate the risk of genetic drift.

(iv) Discussion

HOLLY'S paper: FRANKEL asked about the size and population density of the maize plot shown on one of the slides. Are land races or lines being preserved in Hungary? HOLLY replied that the maize plot had 4-5,000 plants with 400 cucurbits as a mixed crop. Most of the land races of other cereals have disappeared owing to the use of improved varieties but the maize material was collected as landraces more than 20 years ago and regenerated. Some local types could still be found in extreme habitats with poor soils.

FRANKEL'S paper: TEMIZ wished to speak about the Turkish programme in view of FRANKEL'S opinion that his experience with wheat in New Zealand supported the idea that any other region of the world with similar climate would be just as suitable as the original collecting region for regeneration of stocks. Economic plants in Turkey were classified into eight groups for study i.e. cereals, vegetables, industrial crops, horticultural crops, forage plants, forest plants, medicinal plants and food legumes. About 2,500 accessions are collected annually from different parts of the country and 2-3,000 accessions are regenerated annually. Twenty-six institutes throughout the country help with regeneration. Material adapted to the eastern parts of Turkey is sent to an experimental station near the Iranian border. Apricot is rejuvenated in Central-Eastern Turkey which is the main region for production. Some materials are maintained or rejuvenated in national parks. He emphasized that materials are maintained or rejuvenated as far as possible in the actual places from which they came or as closely similar environment as possible. ESQUINAS said we must look into different aspects and consequences or allelic distributions in small populations. He referred to work on alloenzymes of Drosophila species. Allelic frequencies varied after a few generations when populations were maintained in environments different from those in which they were collected. Would the same changes occur in the invisible characteristics of plants rejuvenated in different environments?

GENERAL: CHANG said that accessions should be re-identified at the time of regeneration. HAWKES emphasized the need to ensure maximum reduction of inter-plant competition and maximum survival so that all alleles and genotypes are represented proportionally in the population. FRANKEL thought inter-plant competition was irrelevant provided survival was maximal and equal aliquots of seeds taken. Wider spacing would be helpful. JAIN had found that nature conservationists were very anxious to conserve wild relatives of crop plants when their value was pointed out. As regards the calculation of genetic drift losses, he was not sure that they were being computed properly. Most of the figures given might be based on numbers of generations involved rather than single generation loss. Also, the probabilities are averages of sub-groups or sub-lines. One should be very careful in applying them to few generations and few lines. SASTRAPRADJA pleaded for the international agencies to make a cooperative effort towards in situ conservation. IBPGR should reconsider its policy not to support in situ conservation and leave this to UNEP only. FRANKEL said surveys to determine the wild relatives of cultivated plants in national reserves could be done without international help. National programmes should undertake surveys of the floristic composition of their national parks and of the genetic resources. MEHRA said that nature reserves were often in inaccessible areas, hence the lack of information about them. They were managed mostly by animal specialists. Plant scientists should be involved in their management. He thought the agencies such as IBPGR, UNEP and IUCN should convene a Working Group to coordinate their efforts in support of in situ conservation and to prepare a plan of action and a follow-up programme for research and training. PALMBERG spoke of the support given by FAO to the conservation of forest genetic resources. In many cases, conservation areas need to be extended. WILKES mentioned that the forest preserves for pines in Central America exactly overlap the distribution of teosinte, the closest wild relative of maize, wild Phaseolus beans and avocado. Thus wild relatives of crop plants and forestry genetic resources could be preserved in the same reserve. FORD-LLOYD agreed it was important to preserve the genetic composition of samples. However the aim should be to conserve as many alleles as possible and not necessarily a specific genotype. This would be impossible in an out-breeder. Does Sir Otto think changes of allelic frequencies are relatively

unimportant so long as alleles are not lost? To preserve allele frequencies during regeneration would add to cost. FRANKEL replied that most crops are selfed and allele frequencies in inbreeders would not change since regeneration was a rare event. Change would have to be tolerated in out-breeders. The economics of regeneration was not a big factor for small plots. SMITH said that the regeneration of wild species in a collection could be more costly than collecting them again. KJELLQVIST observed that the regeneration of wild species was new ground; know-how was lacking. PRESCOTT-ALLEN remarked that the great range of protected areas was itself a main reason for conducting surveys to find out what was there. Signs of sectorism between crop, forestry and animal genetic resources were appearing. Efforts should be coordinated to avoid giving managers of reserves guidelines from all directions. STANWOOD referred to sample size required for regeneration. As a matter of perspective, NSSL had 120,000 accessions, representing 12,000 species, with a 10 percent yearly increase. The concurrent questions were: what sample size was needed at regeneration to maintain a particular accession and how much material should be kept in the seed store. Has the IBPGR any recommendations? FRANKEL said that samples had been spoken of as if they were always populations whereas in many collections particularly the older ones, they were not. Many of the accessions at Fort Collins had been pure-lines and the problem of genetic drift did not arise. Until 10 or 12 years ago, one did not think of preserving populations. The IRRI rice collections are pure lines. With selfed material, size of sample is a matter of convenience and the problem should not be exaggerated. WILLIAMS said IBPGR planned to produce a manual on genebank management in a year or two and this would include advice on these difficult problems such as sample size etc. Some of the problems reflected past failures; for example, the need to regenerate small samples from old collections that were badly kept. We still do not know what is present in the older collections. It was virtually impossible to regenerate the out-crossing material; in a collaborative programme on beet, only a very limited number of samples are dealt with per year. The aim should be to store large samples of known material originally in order to defer the need for regeneration. HAWKES expressed the view that reserves on the high plateaux and in tropical forests of South America were not suitable for wild species of potato. To extend the reserves in suitable places would use good agricultural land and so emphasis must remain on genebanks. OLEMBO could not quarrel with HAWKES' conclusion. He informed the Conference that UNEP planned to convene a panel of experts in 1982 to collect quantitative data about the minimum area required for *in situ* conservation of particular species. PRESCOTT-ALLEN said that although potato wild species may be an exceptionally difficult group, there were not the hard facts to generalize about whether or not a good reserve would adequately guard wild relatives of crop plants. Reserves can be managed for different purposes; it is accepted practice in nature conservation. LOPEZ said that in Colombia reserves were becoming a social problem as the land was needed for food production because of population increase.

2.5 GERMPLASM EXCHANGE

Session Convenor: R. Smith

(i) Principles and practice of germplasm distribution and exchange

R. Smith

Previous Technical Conferences have proposed that a global genetic resources network composed of a relatively small number of such centres should be established. Each centre would have a clear responsibility for the conservation of germplasm on either a regional or crop basis. The clear definition of the role and restricted

number of these centres was to ensure all potential users of genetic resources would be able to locate, by direct enquiry, a suitable material with greater facility than had been previously possible. In the hope of further increasing the efficiency of the process, it was intended that the holdings of each centre should be collated into a single computer-aided data base.

However, as national genebanks proliferate and more and more collections are accorded the status of genetic resources collections, the likelihood of a potentially useful collection becoming overlooked by users must increase, through the difficulties associated with discovering its availability and whereabouts. Thus, the initial vision of a "Global Network" can no longer be sustained. Indeed, despite a decade or more of concerted international effort to rationalize the exploitation of plant genetic resources, the probability of users locating appropriate material with precision and ease may not have significantly increased.

(ii) Safe and rapid transfer of plant genetic resources: a proposal for a global system — L. Chiarappa and J.F. Karpati

The international transfer of plant propagation material for research, breeding, collection and conservation involves the concurrent risk of large-scale distribution of plant pests and pathogens. In many developing countries the national plant quarantine systems are deficient.

Against this situation there is the need to accelerate and expand the introduction of new and better crop varieties to meet the increasing requirements of the developing world. Governments, international aid agencies and research organizations are aware of this need and are willing to foster these activities. However, the benefit to be derived from these plant introductions must be measured against the risks. This creates an uneasy situation which often results in insufficiently justified denials or in delays of plant importations, destruction of valuable germplasm consignments, etc.

An IBPGR task force recommended that a new standard be established for germplasm only: complete freedom from plant pests and pathogens. This new standard would encourage research institutes to free and filter out from their germplasm many of the pathogens frequently associated with true seed or vegetative propagation material and provide a safeguard applicable to all plant introductions.

A new certification was also suggested to secure international acceptance and thus to facilitate rapid entry through quarantines.

Subsequently, the matter of plant germplasm transfer was presented to the Government consultation on the International Plant Protection Convention in 1976. Although no decisions have been taken, during the last few years considerable progress in the production and transfer of healthy germplasm has taken place and a meeting of international centres, IBPGR, FAO and others is being convened to discuss the global system.

(iii) Discussion

On SMITH'S paper: Concerning germination procedures, ELLIS said that ISTA issued good advice but the specialist used his own methods. A paper was in press

about imbibition injury and hard seeds in legumes. KÅHRE said ISTA methods were quite successful but might be inadequate for primitive and wild material especially as regards dormancy and hard seededness. In Seed Science and Technology, the ISTA proceedings, there were many papers about these two behaviours and he would welcome further contributions. Hard seededness may have a conservation aspect: hard seeds of clover had been on test since 1926 at his Institute and about one seedling appeared every year. SMITH said the need always to provide germination percentages and procedures should not be overlooked when exchanging germplasm.

On CHIARAPPA'S and KARPATI'S paper: GROBMAN pointed out that quarantine treatment for bulk commercial seed was far less restrictive than for scientific samples. Plant quarantine services should play an active role and bring in and clear seeds ahead of breeders' requests. Five Andean countries had prepared a list of pests and diseases common to them all and used a similar quarantine certificate. He thought FAO should convene a conference on the subject of quarantine. KARPATI referred to shipping large tonnages of grain for food and planting. The best that can be done is to advise local officials, perhaps treat before shipment, pre-sample for examination, or send a specialist with the shipment to help reduce the risks of introducing pests. MEHRA said that if a Working Group is formed to consider quarantine problems of exchange, advantage should be taken of the experience of Australia, USSR and USA in the exchange of material as well as that of International Research Centres. TEMIZ pointed out the differences between commercial samples and germplasm material.

General: NIRULA said ICRISAT conformed to local regulations and had despatched 200,000 samples of sorghum, millet, chickpea etc. to 115 countries with no complaints. ESIABA said that scientists should enquire about quarantine regulations before sending material, otherwise there was a risk of it being destroyed. Quarantine is not a barrier but a filter against pests and diseases to protect a country's plants. In Ibadan, records are kept of introductions and re-introduction is avoided when possible. When large quantities are sent, a small sample is grown in quarantine and it is from this sample that material is released. BRAUER agreed there was imbalance between the treatment of commercial seed and germplasm. An effort should be made internationally to establish a system whereby germplasm is clean and does not carry diseases or pests. SIMMONDS strongly recommended the idea of 'third country' intermediate quarantine stations for clonal plants such as banana and sugarcane. Material could be submitted to a high level of inspection and then passed on. Costs would not be excessive. WILLIAMS stressed the need for full and free availability of germplasm to all who can effectively use the material. Requests are often vague and non-specific, a fact that pointed to the need for an educational role in germplasm work. The pattern of distribution showed the lack of plant breeders in the third world. WHITE said much material is exchanged directly by plant scientists without reference to quarantine. Communication was needed with these people to regulate exchange and quarantine. TEMIZ said his institute had sent out 17,000 samples but received virtually no feed-back.

2.6 CHARACTERIZATION AND EVALUATION I

Session Convenor: N.W. Simmonds

(i) Principles of characterization and evaluation

N.W. Simmonds

The ultimate object of making and maintaining a great crop collection is that it shall be useful, primarily to plant breeders as sources of breeding material for

local improvement and also to scientists interested in the crop (e.g. botanists, geneticists, biochemists). Both the maintainer of the collection and users of it will need information about the entries in it. The question is: what information? The information available about an item in a collection is potentially infinite because it might contain not only "passport" data and morphological descriptions but also performance data for many characters distributed over indefinite numbers of years and environments. In practice, therefore, the information recorded and assimilated into any one working data base must be restricted in scope and strictly confined to what is both useful and usable. The now well-established distinction between characterization and evaluation emerges directly from these considerations.

Characterization is basic. It is the assembly, in an orderly form, of essential circumstances-of-collection (= "passport") information, together with a skeletal morphological description of the entry. The former need no special comment: it will start with the accession number and include (when available) an abstract of the original collector's record as to place, date etc. of collection. The latter component will be based on an agreed, orderly list of "descriptors" for the crop, each categorized as to two or more possible "descriptor states". Whether morphological or (more rarely) physiological in nature, descriptors and their states are chosen to be reasonably constant in expression and little subject to environmental variation or to GE effects. There has perhaps been a tendency to make descriptor lists too long and complicated but it is now generally accepted that the basic first step is a "minimal list" to simplify both recording and computing; elaboration can follow but only if and when it has been shown to be necessary. Given characterization along these lines, the keeper of a collection can do two essential things. He can: (1) scan the collection for possible identities as a first step in reducing duplication; and (2) respond to generalized requests from scientists and breeders for categories of material ("tetraploids with purple-splashed-white tubers", "plump-grained glutinous rices from Java", "short-strawed sorghums with dense heads from middling elevations", and so on). When a collection can respond quickly and efficiently to such requests, it is doing what is essentially required of it. If, with knowledge improving over time, elaboration of the descriptor list seems desirable, the choice of new characters for inclusion will follow the principles given above: that descriptor states should be constant in expression over varied environments.

Evaluation, as the word implies, is concerned with determining the usefulness of an accession for a specific purpose in specific circumstances. It is thus concerned with economic characters which will in general be different from the diagnostic minutiae which are useful for characterization. Economic characters are commonly polygenic (showing continuous rather than discrete variation), much subject to environmental influences and subject also to GE effects. They are more often physiological in nature than morphological and in general can be assessed only by specific experimental test, the results of which have meaning only for the environment in which the test is performed. Obvious examples are yield, many quality characters and most disease resistances (even major gene resistances when the distribution of pathotypes is incompletely known). Evaluation in general must be carried out by the breeder who proposes to use the material; rarely, he will be able to use results generated by a colleague working in a homologous environment elsewhere; more usually, other workers' evaluations will be at best useless, at worst outright deceptive. The problems are, of course, exacerbated by non-standardization of testing techniques and scales of scoring or measurement.

In short, evaluation data are location-specific; they are of vital importance for the breeder-evaluator himself (and for a few colleagues elsewhere); but they are not finite and generalizable in the way that characterization data are. The man in charge of a collection will want to know the broad results of major evaluation activities on his materials and may wish to incorporate some minimal cross-reference to them in his data-base; but he will not attempt to incorporate evaluation data as such. For a major collection, efficient characterization alone is a substantial task and must remain the first priority.

These principles clearly have to be applied in a flexible, empirical fashion. Each crop will pose specific problems. Descriptor lists may well have to be amended in the light of experience. (Sometimes by the addition of allozyme data, for example.) Some curators may find it impracticable to use certain descriptors in their local conditions. Again, there is bound to be an overlap in the categories, a common zone of characters relevant both to characterization and evaluation. Also, while physiological or performance characters will usually be inappropriate to the characterization process, there may be occasions when they can be effectively included; day length response/maturity time observed under a standard sowing date or the very occasional disease reactions which are location-non-specific come to mind as examples. But the restriction of characterization to those data essential for the efficient operation of the collection must surely remain the primary objective.

(ii) Principles of evaluation S.K. Jain

All genetic resources have to be described in terms of genetic and phenotypic variation for a large variety of traits. Often a distinction is made between the biosystematic and the economic goals such as to emphasize the terms characterization and evaluation. Accordingly, a minimum descriptor list is prepared for each species that emphasizes this distinction. However, several points should be made: (1) Assays of genetic variability in genetic resource accessions are frequently of interest primarily in relation to the discoveries of evolutionary processes, geographical patterns of variation, breeding structures, etc. all of which are of interest to the breeder as well; hence, the use of allozymes, analysis of seed proteins and other factors, morphological Mendelian loci, quantitative traits, ecophysiological parameters and resistance to diseases and pests are complementary ways of describing variation; (2) Many of the characterization traits have been and might be increasingly used in the breeding programmes (e.g. degree of pubescence for resistance; plant growth types in ideotype selection); (3) Use of wild relatives in particular requires a combination of biosystematic and breeding approaches in developing useful germplasm. A basic principle of evaluation would suggest that (a) a minimum descriptor list be used as a mere guideline for standardized documentation in the initial stages, and (b) further genetic description be continued as facilities, interest of a collaborative team and specific needs warrant it.

The choice of entries, locations of study, characters scored and specific biometrical analysis will depend on the goals of a researcher. Screening for a disease resistance gene or an aminoacid component (e.g. lysine content) may simply require processing of thousands of entries, or alternatively, just a few for further detailed genetic analysis. Quantitative aspects of ecophysiology increasingly require field evaluation of a large number of genotypes and populations using rapid assay procedures. The classical yield components and plant form variables need to be scored

using an appropriate experimental design in order to estimate genetic versus non-genetic components. At least, replication and randomization suitable for the analysis of variance are required. Catalogues should allow a description of results in relation to the statistical validity of estimates reported. Breeders' experience should be incorporated in the data banks so that genetic resources used by different workers can be compared. Descriptor lists should reflect the flexible needs of systematists, breeders and other plant scientists.

The past evaluation work in several major crops has been reviewed in relation to the "principles" outlined above. It is apparent that for a selected few crops and certain subsets of their genetic resources, evaluation has been very extensive. However, a great deal of review effort and field research are needed to achieve this for the other materials. Data from our own work on several crop genera were presented with emphasis on the biosystematic objectives in wild, weedy and crop materials. Basic training in genetics, statistics, evolution and plant breeding would be highly desirable for researchers at the genetic resources centres but, in addition, greater collaboration with basic scientists at the universities and research stations should be forthcoming.

(iii) Time-related problems in the evaluation of forest genetic resources — J. Burley (read by A Greaves)

Genetic evaluation of forest trees is required at two levels, between populations (trials of genera, species and provenances within species) and within populations (classical selection and progeny testing within a provenance). These two levels differ in the pre-requisite information and in their objectives but they share with all silvicultural and forest genetic research three differences from agricultural evaluation - time, space and available knowledge.

Trees are long-lived organisms that require considerable growing space: plantations are not far removed genetically from wild types and generally maintain appreciable genetic variation, thus requiring large numbers of individuals for precise estimation of means. These two features necessitate large experimental areas with the associated problems of site heterogeneity, replication and complexity of design. Character assessment and analysis need to be repeated at several periods throughout the rotation because genotypic rankings and estimated of genetic parameters may change with time; this emphasizes the need to determine juvenile-mature correlations.

However, in view of the rapid rate at which natural forests in developing countries are being destroyed, the forester is compelled to give priority to the identification and conservation of those genetic resources which offer the greatest immediate practical benefits. Nevertheless, it is recognized that the intensive evaluation of the full range of genetic variation is essential for the formulation of effective tree improvement strategies. These short and long-term objectives need not conflict if evaluation, conservation and genetic improvement proceed along parallel courses, with provision for the modification of procedures if it is shown to be necessary.

Examples of international cooperative programmes of exploration, conservation and evaluation were described and sources of short-term and long-term training noted. Details of assessments undertaken for a major international provenance trial of tropical pines demonstrate the multivariate nature of forest tree evaluation and

indicate the problems of storage, retrieval, analysis and interpretation of resultant data.

(iv) Evaluation of wild relatives of crop plants J.R. Harlan

Wild relatives of crops have been underexploited because: (a) plant breeders are not familiar with them, (b) they do not wish to deal with deleterious genes and/or sterility, (c) they are confused by inept taxonomy, (d) they have not been instructed in their use, (e) collections are inadequate and poorly maintained, (f) it is more pleasing and satisfying to intercross elite material and avoid the trouble of non-adapted material, (g) prejudice or other reasons.

Experience has shown however that wild relatives can make enormously useful contributions to plant improvement. They have evolved over a longer period of time than domesticates and have co-evolved with the diseases and pests. Wild races and species have provided sources of resistance to diseases, pests, cold, heat, draught, excessive rainfall, high and low light intensity and so on. They have been sources of semi-dwarf growth habit, cytoplasmic male sterility, better quality, photosynthetic efficiency, increased variation and higher yield.

Most crops have wild races that belong to the primary gene pool and sterility or gene exchange are not problems. Ultimately we will need to use all the variation we can assemble and everything that is within genetic reach. We are short-sighted, indeed, if we ignore the gene pools at our doorstep. Unfortunately, these gene pools are being ignored because they have not been adequately collected and because they are poorly understood. Detailed analyses of the natural diversity of wild populations are badly needed. The deployment of natural defenses against diseases and pests requires special emphasis.

Most importantly, we cannot evaluate materials that are not available. Collections of wild relatives of most crops are woefully inadequate. Further, wild races require special care in maintenance and genetic erosion among collections is often very rapid. Special care in maintenance includes: (a) being thoroughly familiar with the material in order to detect and avoid mixtures and volunteer plants, (b) bagging to save shattering seeds, (c) artificial selfing or sibbing to save genes and gene combinations, (d) dealing with contamination of the soil with dormant seeds, (d) managing seeds that are difficult to germinate, and (f) preventing the escape of weed pests. The extra care is substantial and must be accounted for.

(v) Discussion

JENKINS said the management of 2 x 10 items of information was a formidable problem. What kind of data base is used by the Oxford Department of Forestry? GREAVES replied our data base management system is being devised; we hope eventually to combine the data from many trials into a single data base. MEHRA observed that at the last Technical Conference we were urged to collect population samples. What does SIMMONDS have to say about the characterization of such possibly heterogeneous material, bearing in mind the need to describe collections so that users know what is in them? SIMMONDS said there are no difficulties with inbred lines and clones. For heterozygous or heterogeneous collections there is no general solution; common sense must be used. Clearly a list of discrete descriptors is not well adapted for continuous

variation. JAIN said with a population sample, you may wish to describe genetic diversity or you may wish to record a series of discrete descriptors. We try to describe the number of distinct genotypes in a population sample and the model genotype. Other statistics like range, mean and variance are useful. CHANG said that in characterization and evaluation at IRRI quantitative characters were recorded during the main growing season. Qualitative traits are studied in the "off" season so spreading the work load. The descriptor list used is the minimal list; other workers are free to add more to meet their own needs. GIACOMETTI said that his comments were based on thirty years of experience acquired by his research organization. We find that stratified sampling is difficult. Sometimes we collect very small samples of maize and so have genetic drift. Maintaining our maize collections is difficult; we make crosses in pairs to maintain variability. JAIN observed that having collected a population sample, there were two objectives: (1) to define those traits of interest - the descriptors; (2) to define the amount of genetic variation in the sample using whatever methods are available. FRANKEL said this is true not only of heterozygous samples but of any collection which is not uniform. CHANG reminded participants that the main users of germplasm are not only the breeders but also entomologists, pathologists, etc. KRANSKI referred back to quarantine. The regulations are to protect countries from importing pests and diseases. The direct exchange of material between breeders had not been stressed. They have a personal responsibility to obey regulations. Quarantine problems could not be solved in a Conference such as the present one. FRANKEL said he would like to question SIMMONDS' distinction between stable and non-stable characters for evaluation. How is one to know if a character is stable? Where would the rice breeder be without IRRI's disease evaluation data? Are these disease responses stable and location specific characters? He could deduce something useful from records of observations on crops he worked with taken in climates not too different from his own. He found it hard to exclude almost any kind of observation from an evaluation study, whether a domesticated or wild species. It is hard to separate stable and non-stable characters. SIMMONDS agreed it was not easy because there is much overlap between the two. The number of characters for evaluation is potentially infinite but in real life we must give the curators of collections a finite task. ABIFARIN asked for further clarification about the evaluation of populations and pure lines. For example, we receive sets of rice samples for evaluation of response to iron toxity. Sometimes the accessions are heterogeneous with different responses within them. How do we report these data to our collaborators? JAIN replied that the decision had to be taken first whether to describe genetic variability. If so, then variants must be taken, numbered and the mean, range, etc. of characters recorded. Referring to HARLAN'S paper HAWKES commented on the value of wild species and spoke of a programme at CIP of wide crosses followed by backcrossing as an essential part of potato breeding. Such "pre-breeding" would help to overcome the reluctance of breeders to use wild species. They must be preserved in collections. HARLAN thought it was partly an educational problem. He was shocked by the number of breeders who did not know the wild relatives of the crops they worked with. CHANG said that in rice, wild species may have evolved a co-adaptation with pest and diseases. During evaluation the presence of "escapes" must be watched for in collections. Often breeders cannot grow wild species because their seeds do not germinate. DE LANGHE told HARLAN of a collection of Phaseolus species held at Gembloux, Belgium. MOTA said breeders want quick results. Perhaps geneticists had not given them enough information about wild species to enable breeders to use them. JAIN said courses at the university dealt with crop evolution; it was during such courses that breeders should learn about wild species. GIACOMETTI said that high

priority was given to wild species in the Brazilian work on Arachis, Manihot and pineapple. CIAT was now interested in wild species. They had 17 wild species of Manihot that are sources of resistance to mites, mealy bugs and bacterial blight. In Africa, resistance to cassava mosaic virus had been bred into cultivated clones from M. glaziovii. The hybrids were also resistant to bacterial blight. SINGH asked HARLAN whether wild species might have physiological characters that would enable breeders to go beyond the plateau of biomass production on which many of our highly evolved cultivars now rested. HARLAN replied that it was not unusual to have heterosis in wild x cultivar hybrids but this is usually accompanied by a decrease in harvest index. However, this does not mean that we cannot make use of the heterosis. MENGESHA said ICRISAT is now very active in the collection of wild species. The efforts with sorghum were disastrous because samples with closed glumes are destroyed by the quarantine service as hazardous weeds.

2.7 CHARACTERIZATION AND EVALUATION II

Session Convenor: J.R. Harlan

(i) Evaluation of germplasm: a case for rice

T.T. Chang

The diverse rice germplasm conserved by IRRI undergoes a long process of systematic characterization and evaluation. During initial seed multiplication the Germplasm Bank (GB) staff takes systematic records on 38 traits to provide a comprehensive morpho-agronomic characterization of the collected samples. During the characterization process those samples with identical or similar names are compared and differentiated into obvious duplicates, morphologic variants or eco-strains. Meanwhile, reactions to two fungal diseases are obtained by inoculating the growing plants.

Numerous resistant sources identified at IRRI are further channelled into the International Rice Testing Program (IRTP) under respective nurseries. Worldwide testing by rice scientists in many national programmes have broadened the eco-genetic base of the desirable sources and accelerated their utilization.

Data files of the GB, Genetic Evaluation and Utilization Program (GEU) and IRTP are computerized and interlinked so that desired information can be quickly retrieved, analyzed or presented in different report formats. Moreover, the above files are also linked with files on the origin and pedigree of improved lines and varieties. Notebooks of field experiments can be printed by the computer to provide complete and up-to-date information on the above aspects.

Information and seeds provided by IRRI have assisted the rice researchers of the world not only in a more complete utilization of the germplasm - both unimproved and élite - but also lent impetus to collaborative research across national and institutional borders.

Seeds multiplied from the conserved stocks are channelled into various screening tests of IRRI's GEU. Multidisciplinary efforts are coordinated to provide data on biotic resistances and eco-edaphic tolerances up to 37 traits. Systematic testing is performed by teams of scientists in eight groups: agronomic characteristics, grain quality and protein content, diseases, insects, drought, temperature, temperature stresses, deepwater and flood, and adverse soils. Resistant or tolerant reactions are verified by repeated testing or expanded testing. Rice varieties recently collected from remote areas and reputed to possess special characteristics are given priority in the screening process.

(ii) Evaluation and documentation of germplasm: Southeast Asian experience — R.B. Singh and N. Chomchalow

The IBPGR Southeast Asian Regional Genetic Resources Programme is an effective cooperative network for capturing, conserving and utilizing plant genetic resources. Regional crop priorities are kept under continuing review and funds allocated accordingly. The national collections are duplicated at a common agreed regional genebank. Further, the Regional Programme had not only catalyzed but also assisted in various genetic resources activities.

Sizeable collections of rice, maize, grain legumes including soyabean, peanuts and winged bean, tropical fruits, especially mango, durian and rambutan, bananas, vegetables, tuber crops and coconut have been established.

Evaluation, documentation and utilization of the germplasm have not kept pace with the collection activities, but now they are receiving due attention.

Varying levels of interaction between curators and plant breeders exist. In some of the countries germplasm activities far exceed the breeding activities and under such conditions the evaluations done are biased towards botanical characterization. In the other countries the plant breeders combine the responsibilities of curator, evaluator and user, thus adversely affecting one or other of the activities.

Long life-cycles, constraints of land and manpower and sometimes lack of basic information on biological attributes of perennial populations have hindered the evaluation and use of germplasm of tree crops. Improvement of these crops has been restricted to selections from introductions. However, hybrids and breeding populations in industrial plantation crops are under various trial stages.

The Regional Programme has produced descriptor lists on tropical fruits, winged bean, taro, yam and mungbean. These and other descriptors issued by the IBPGR are under effective use in the region. For most of the crops data are recorded and stored on manually prepared data sheets. However, in some cases computer-based catalogues and print-outs have been generated and data filed on magnetic tape in machine-readable form. Data base management has helped locate duplicates, identify collection and conservation gaps and inefficient exchange of information and use of the collections. Genetic divergence and adaptation patterns in winged bean have been analyzed.

Directories of the collections in the region have been prepared and a quarterly Newsletter highlighting the ongoing germplasm activities is brought out and widely distributed.

(iii) The evaluation of potato germplasm at the International Potato Centre (CIP), Peru — Z. Huamán

CIP has emphasized the collection, maintenance and evaluation of the cultivated germplasm of potato. Coordinated expeditions involving scientists from several countries have collected some 13,000 clonal accessions from throughout Latin America. Since all of these accessions have to be maintained by annual field plantings it is important to keep them free of disease and to eliminate redundant duplicates. The

first step in the evaluation has been the proper taxonomic identification of each accession. Within species data have been accumulated on morphological traits and reaction to pests according to a list of descriptor names and states which has been developed and published. Manual and computer procedures have been used to group genotypes into possible duplicates according to all available data. Once an electrophoretic analysis has confirmed a duplicate, and seed from controlled pollinations has been obtained, the duplicate is eliminated from clonal propagation and maintained only as seed. Through this procedure the collection had been reduced so far to about 8,000 clonal entries. These accessions are being subjected to further evaluations by CIP staff and all of the data are being accumulated in a computerized system. The data bank has almost 13,000 records each with a possibility of 56 descriptors. This system provides scientists with ready access to data and facilitates the use of potato germplasm in breeding and evaluation research.

(iv) Germplasm evaluation at Gatersleben, DDR; the relationship between genebank and breeder — C. Lehmann

The Gatersleben germplasm collection of the Central Institute for Genetics and Cultivated Plant Research comprises at present 48,959 accessions almost exclusively from temperate regions.

The basic objective of the genebank is to provide raw material for plant breeding.

The evaluation of this material is carried out in cooperation with specialized institutes in the GDR.

Plant breeders in the GDR cooperate closely in crop specific breeder collectives in which staff members of the genebank are fully integrated. In this way the custodians of germplasm collections are constantly informed of actual and planned needs for genetic material for incorporation into current and planned breeding programmes. They inform plant breeders of the material they possess that meets these needs.

Information on genetic material given to breeders - results on special observations and investigations by breeders - flows always back to the genebank and completes evaluation data of respective accessions.

There are three sources of evaluation data: from the genebank (mainly morphological and phenological characters), from specialized institutions (disease resistance and quality characters) and from plant breeders.

The results obtained from screening the barley collection for resistance to mildew, leaf and stripe rust and loose smut were described as an example of evaluation.

(v) Discussion

PERNES suggested that evaluation data should be classified using a broad numerical taxonomic system so that it would be easier to meet requests from breeders when there was full knowledge of the major groups in the genebank. More should be done to tell breeders of this broad classification. CHANG said that an empirical system

was used at IRRI, e.g. under the GEU, 101 was genetic resources, 102 disease resistances, 103 insect resistances, 107 drought resistance and so on. Information was classified this way in the IRRI Newsletter. Thus it was quite easy for rice researchers to find the appropriate categories and information; 2,000 copies were distributed annually. PERNES replied that CHANG'S example concerned direct application; he meant a classification to indicate genetic distances between groups and to indicate genetic variability. HARLAN said PERNES was referring to clustering and other techniques that could be applied with the information available. ABIFARIN asked what was to be done about commercial varieties. Should they be collected and stored? CHANG said obsolete and new varieties are kept by IRRI whether national or base material. A number of breeding lines were also kept. They found considerable redundancy between genebanks and many centres lacked a dialogue between curator and breeder. MEHRA spoke of the inconsistent results obtained in Indian studies of clustering etc. One must be sure that the characters studied are not affected by environmental changes. SINGH said that the techniques of multivariate analysis had been valuable, more so than MEHRA indicated. SINGH thought curators should not be asked to maintain all such data. They can be published in journals. SIMMONDS thought taxonomic biosystematic studies were valuable but not the job for a curator. It would dissipate his energies. It was very important to preserve recently obsolete varieties and erosion in them might be worse than with landraces. CHANG said that IRRI was being called on to replace seed stocks in Cambodia. This illustrated the importance of conserving all kinds of varieties. CARDENAS-RAMOS asked how underexploited or minor crops should be characterized and evaluated. CHANG said that all wild species of rice are characterized at IRRI using a descriptor list running to about 85 morphological characters; they are mostly worthless and would be volunteers in the field. Agronomic tests are difficult. If the genomes are very different from those of cultivars, wild material will not be used for a long time. More work should be done perhaps best in universities. SINGH said winged bean had become very popular in Southeast Asia. Very systematic collection, conservation and evaluation was going on. They were learning how to use the material. The same was true of minor legumes and indigenous tropical fruits. TEMIZ thought the discussion was moving away from the main problems. What about crops such as forages, ornamentals, medicinal plants, etc. They raised many technical problems such as shattering in forages and wild types. How was a good supply of seeds to be obtained; what were the techniques for propagation, rejuvenation and so forth? GIACOMETTI said CIAT was giving special attention to forage crops, mainly legumes. It now held 3,000 accessions of 11 genera. Evaluation studies suggested Zoria may be a more important genus than Stylosanthes for forage. There was also a data bank on 12,000 accessions of wild material. An expedition was only regarded as concluded when all the material had been identified. JENKINS asked if LEHMANN only considered data of wide applicability when dealing with feed-back to his information system. LEHMANN replied that data on characterization and evaluation belonged together and were so treated. SIMMONDS commented that a data base could not go to infinity; it must break before them.

2.8 DOCUMENTATION

Session Convenor: J.A. Warren

Dr. Warren was unavoidably absent for part of the Session. Before reading Dr. Warren's paper, Dr. Williams said that he would like to remind the Conference that as yet few centres were actually involved with the data aspects of their collections. The Conference could discuss theoretical optimal situations in which genebanks are exchanging data, in which there is a maximum of compatibility and all such types of con-

cepts. However they would remain theoretical until put into practise in the field and in the institute. As regards documentation, we relied heavily on the experience of the developed world. Most of the data management systems that are being used for genetic resources are in the developed world and the transfer of technology to the developing world was not easy; particularly in relation to many aspects of the equipment required, training needs and so on. Currently we needed the spirit of the old days when botanists had a standardized routine for collecting herbarium specimens, identifying them and putting information on the labels. Points like these should be borne in mind during the discussion of the papers about to be presented.

(i) Information capture and the rapid feedback of results J.A. Warren

Over the past five years, it has become increasingly clear that one of the major bottlenecks that interferes with the effective development of germplasm data bases is failure to store data in a computer readable form. The persistence of this kind of bottleneck should be regarded as intolerable because most computer systems can be set up so that the same data entry operations that produce preliminary summaries for a trial or a collecting mission at the same time can provide machine readable records suitable for later analyses or incorporation in data bases. The fundamental need for accurate, machine readable records should be met by the people who originate those records. Ordinarily, they are in the best position to recognize and correct data errors and have the strongest incentive for rapid feedback of results.

Feedback within, say, four hours provides a powerful incentive for storing data because it means seeing answers to questions that are still of active interest and it often permits re-examination of plant materials in the light of questions, conjectures or conclusions suggested by the feedback results.

Most organizations will benefit from timely feedback in terms of percentage trials summarized, percentage data stored in machine readable form and percentage data subjected to field verification.

Investigators now can obtain rapid feedback of results at centres that have suitable computing facilities. Others, even those in small operations at remote locations, will eventually be able to obtain rapid feedback based on microcomputers.

At the present time great care must be exercised in exploring the acquisition of microcomputers. A mechanism is needed for the timely distribution of information about experiences with microcomputers used for agricultural purposes.

(ii) Genetic resources documentation: a progress report C. Howes

In its early years the IBPGR had a conception of a 'system' for computerized documentation of genetic resources to be installed in all genetic resources centres. To this end it supported the development of the EXIR computer programme. With experience gained in the increasing number of genebanks it is now realized that most genetic resources computing needs are relatively simple and can be handled adequately, if not efficiently, by a variety of computer programmes on a wide range of machinery.

The emphasis on communications within the global genetic resources network also focused attention on the problems of transferring large data sets between computers.

In fact, the major communications problems are on a much smaller scale but are even more important. They are - lack of data accompanying distributed germplasm; no feedback to curators by the recipients of distributed germplasm; the difficulty of breeders to express their germplasm requirements in terms of the data available to curators. The development and publishing of widely accepted descriptor lists is intended to ease these communication problems by developing an international germplasm language. Care must be taken in the definition of these lists as scientists of different backgrounds may easily interpret the same words to mean different things. Small scale international cooperative trials can help in identifying such problems.

To help breeders select germplasm, efforts were made to produce centralized data bases for the world's collections of certain crops. Some major collections have published detailed catalogues of their material. It is now recognized that with the collection of new material and data these expensive catalogues are quickly outdated. When breeders request material with specific characteristics the curator should be able to easily identify such material in his collection and despatch it together with all relevant data to the breeder. To help the breeders the IBPGR is now publishing a series of crop-specific directories of germplasm collections summarizing the material held in the major collections, evaluation data available and storage conditions.

(iii) Germplasm documentation: the future S. Blixt

Germplasm collections include the genetic variation of yesterday and today preserved for the future. The plant material as well as the information maintained along with it is expected to be utilized for an indefinite period in the future. It is therefore essential that neither material nor information is allowed to degenerate; when such integrity is maintained, germplasm collections become genebanks.

Degeneration of information is affected by many factors. If genetic information degenerates it does so very slowly. With limited resources, genebank efforts therefore give highest returns when spent on characterizing material, i.e. collecting information on characters with high heritability, recognizable under very varying environments. Evaluation, i.e., the collecting of information for specific breeding or other purposes, should be left for the specialized breeding or other institutes feeding back the information to the genebanks for maintenance.

The developments in breeding and plant research are now moving rapidly towards the use of increasingly sophisticated genetical technology and demands on genebank information can be expected to move in the same direction. It is essential for the success of the genebank concept that information available and information demanded is virtually the same.

Greater awareness of the importance of the quality of the information together with greater complexity and higher demands on utility makes computer-based systems the only realistic alternative, at least for bigger collections. The variation in genetic knowledge of different crops, in economic and other resources and in importance of crops in different regions will probably remain for a long time. It is therefore likely that what is most needed in the near future is not a single, all embracing genetic resources system, but a number of alternatives optimal for a number of different stages of development. These alternatives should give a choice, from

available standard software packages for general data management purposes, to specific genebank and breeding packages, handling all aspects of information management, processing and utilization. One such specific package developed in the Nordic Genebank and Weibullsholm Plant Breeding Institute is briefly presented.

(iv) Discussion

On WARREN'S paper: TEMIZ complained that frequent changes in software caused many problems to users. WARREN said the basic rule is not to accept programmes that are not working and not to change them until their successor provides considerable extra benefits.

On HOWES' paper: GIACOMETTI reported the support received in Brazil from IBPGR for EXIR. However the system could not handle data from 39 member institutes. Workers were enthusiastic about an experimental system of microcomputers that was in use; a series of catalogues had been produced for several crops. WALDMAN also reported success with microcomputers in Israel. She added that descriptor lists for wheat and *Allium* had been drawn up. FORD-LLOYD said the IBPGR's Boulder Group should be recognized as the source of basic ideas on the concepts of descriptor lists and data preparation techniques. WILLIAMS added that much of the work done by the IBPGR's Boulder Group depended on the help of some genebanks to which credit should be given.

On BLIXT'S paper: MANRIQUEI asked if there was a recommended way to deal with data from several sites over a number of years. BLIXT replied that at the Nordic Gene Bank specific data files on multi-location data are held in chronological order. It is easy then to search sequentially by accession number or specific descriptor. It was important to decide which types of character to put in the main data base i.e. means, deviations, etc. and to up-date the entries annually. MANRIQUEI said that accessions were grown in Peru at three altitudes and the responses differed. How could the results from different sites be related? BLIXT replied that the simplest way to deal with such data was to use a compound descriptor so that altitude and location always relate to specific results. A descriptor list should be open-ended and it is up to the specialist to include descriptors aligned to specific requirements. WARREN said foresight is needed for the best results with a data base but it is always possible to include other key fields at a later date. If the data base is inflexible, there might be a need for new software. Many people consider that their problems will require an individual data base system but in universities many users with different requirements all use the same simple data base programme.

General discussion: ESTABA said material arriving at the quarantine station was often poorly identified. It was difficult to identify duplicates. A standard amount of data should always be given with the accession. HOWES replied that all numbers associated with an accession should be distributed along with the sample. HAWKES suggested that where an original collector's name and number are available, these should be used to avoid the confusion of having multiple accession numbers. Where this original number is not available, the oldest known accession number should be used. MEHRA recommended the use of standard varieties as a reference for performance over different years at the same site; the data could then be compounded in the main data base. The method was not recommended for data from different sites. CARDENAS-RAMOS said that SAS is more efficient than EXIR especially in retrieval time. He remarked that the inclusion in the data base of some non-biological descriptors

allowed sociologists, economists, etc. to utilize the data base. STANWOOD raised the following points: (1) the curator must realize that his data system is a tool and should be used as one; (2) flexibility is the greatest asset; dependence on either hardware or software is severely limiting; (3) local control of the data base is essential. The biggest problem could be the transfer of the original observations into the computer. WITCOMBE endorsed the comments made by HAWKES. The collector's number was a unique identifier. In addition, an acronym for the collector's institute and the year of collection were invaluable. Any name given to varieties should always be included.

2.9 UNDER-EXPLOITED CROPS

Session Convenor: S. Sastrapradja

(i) Minor crops in Southeast Asia

S. Sastrapradja

In terms of population, Indonesia is the largest country in Southeast Asia. Among the 147.7 million people, 80% live in rural areas; of these 28.6% belong to the very poor income category. This category includes those households with an income of less than 20 kg rice-equiv./capita/month. Regarding the distribution of the population, the very poor income families are mostly concentrated in Java. The calory intake of this group is less than the recommended level, which is 1,900 cal/man/day for Indonesia.

With regard to food production, the role of home gardens in providing food for the rural poor is important. Minor tuber crops such as Colocasia, Xanthosoma, Dioscorea, Amorphophallus and Canna are grown together with seeds protein resources (Phaseolus lunatus, Dolichos lablab, Psophocarpus tetragonolobus, Mucuna pruriens, Cajanus cajan) and vitamin/mineral resources (Amaranthus, Saurupus, Syzygium aquaeum, Citrus maxima) in the home gardens for daily uses. Home gardens also supply spices for cooking. Species such as Alpinia galanga, Cymbopogon citratus, Occimum basilicum, Citrus amblycarpa and Kaempferia galanga are commonly found as components in the home gardens. For fuel purposes energy-producing plants (Leucena leucocephala, Sesbania grandiflora, Calliandra sp.) are grown.

In some areas, home gardens are planted with cash crops. Species like Myristica fragrans, Parkia speciosa, Gnetum gnemon, Pithecelobium jiringa produce fruits almost all the year round. Such fruits are much in demand because of their multiple uses. (In addition to this group, flower producing plants, e.g. orchids and roses, are becoming more important.)

From an ecological point of view, home gardens are balanced ecosystems. Species are grown in such a way that the highest canopy is occupied by sun loving species and underneath are shrubs and shade tolerant species covering the ground floor. Genetically, most of the species are primitive cultivars with a large range of variability, hence a reservoir for future uses. The place of man in the system was discussed and the need to develop these genetic resources stressed.

(ii) Genetic resources of fuelwood tree species for the improvement of rural living

C. Palmberg

Whereas the importance of conserving and utilizing existing variation is recognized as fundamental in most tree species used in large-scale industrial plantations,

little or no information is yet available on intra-specific variation in a large number of tropical species which today are receiving increased attention as providers of goods and services for rural communities.

At its Fourth Session in 1977, the FAO Panel of Experts on Forest Gene Resources drew special attention to the multi-purpose species which, in the past, have tended to fall between the two areas of forestry and agriculture. The Panel drew up a list of priorities for action by species and activities, laying special emphasis on arboreal fuelwood species in arid and semi-arid areas. Based on the recommendations made by the Panel and at the instigation of and with support of the IBPGR, FAO's Forestry Department initiated in 1979 a project on the conservation and better utilization of genetic resources of these species.

The project was discussed and needs and possible strategies for future action mentioned. In the light of increasing fuelwood shortages in rural areas and of projected areas of plantations needed to meet future demands, the urgent need for coordinated action in exploration, collection, evaluation, conservation and wise utilization of existing genetic resources of arid and semi-arid zone fuelwood species is stressed.

(iii) Changing priorities in genetic conservation: leafy tropical vegetables — D. van Sloten

Introduction

Major emphasis in genetic resources work in the past has been towards the major staple foods, viz. cereals, food legumes and to a lesser extent root crops.

However, the IBPGR in recent years has expanded its programme to include many more crops, and it has indicated that programmes on some of the major cereal crops is nearing completion. The result of this will be that more attention can be paid to other crops, hence the term - changing priorities - in the title of the paper.

Horticultural crops in general and in particular leafy vegetables have not, until recently, received the attention they require, possible because: (a) the total production is underestimated; (b) the value as a cash crop for small farmers has not been sufficiently realized; (c) the nutritional value has not been fully recognized.

A large number, possibly over 1,500 species, of wild and cultivated plants in the tropics are used as a leafy vegetable. Most of them are not well known, nor widely distributed, and have limited potential. The most important leafy vegetables in the tropics are listed below:

(i) Annual hot season leafy vegetables (*Amaranthus* spp., *Imomoea aquatica*, *Corchorus olitorius*, *Xanthosoma brasiliense*, *Basella rubra*, *Solanum* spp., *Talinum triangulare*, *Celosia argentea*, *Hibiscus sabdariffa*);

(ii) Annual cool season leafy vegetables (*Brassica* spp., *Lactuca* spp., *Beta vulgaris*);

(iii) Perennial leafy vegetables (*Moringa oleifera*, *Vernonia amygdalina*, *Cnidoscolus chayamansa*, *Sauropus androgynus*, *Abelmoschus manihot*);

(iv) Leaves of food crops grown for other purposes (*Manihot esculenta*, *Ipomoea batatas*, *Colocasia esculenta*, *Vigna unguiculata*).

Production data of leafy vegetables are even more difficult to find than those for other horticultural crops. An investigation of local tropical markets would give a better idea of production, an effort which is currently being undertaken by FAO.

Although there are exceptions, in general the consumption of leafy vegetables in the tropics is far from optimal, especially if one considers that the fulfilment of vitamin A requirements in tropical regions very often depends on vegetable products and especially on leafy vegetables.

Leafy vegetables generally have a low economic value and social prestige. Many leafy vegetables are produced for home consumption or even gathered in the forest. A number of perennial leafy vegetables may be found in home gardens. These deep rooting and highly drought-resistant vegetatively propagated shrubs are of low economic importance but are an extremely good source of leaves throughout the year. The most important market vegetables in the tropics are Chinese cabbage, amaranth, jute, taro, kangkong, Solanum spp., lettuce and spinach beet.

There are two major reasons causing genetic erosion in leafy vegetables:

(i) the introduction of modern cultivars (e.g. Brassica spp. and to a lesser extent Amaranthus spp.);

(ii) the introduction of European type vegetables in the tropics, which are more prestigious than the local leafy vegetables, slowly causing the latter to disappear.

Genetic improvement programmes have concentrated mainly on the temperate leafy vegetables. Very little work has been done on the improvement of tropical leafy vegetables, possibly with the exception of Amaranthus.

The IBPGR has assigned high priority for action to eight major groups of vegetables among which are the brassicas and amaranths. A slightly lower priority has been assigned to a large group of vegetable crops, among which is a considerable number of leafy vegetables. It is envisaged that these crops will mainly be dealt with by regional and national programmes.

(iv) Genetic resources of medicinal plants R. Gupta

Plants remain as the major source of medicaments and were amongst the first to be used by man. The principal botanical drugs in world trade are Cinchona, Dioscorea, Foxglove, Ginseng, Gentian, Psyllium, Opium, Senna, Rauvolfia, Cathranthus, Belladonna, Aconites, Aloes, Ammi majus, Pyrethrum, Henbane, Ipecac, Liquorice, Rhubarb, Nux-vomica, Stramonium, Valeriana, Vinca and a few others. Most of these raw materials are gathered from their wild habitats and some from cultivation in India, South Korea, Brazil, China, Kenya, Yugoslavia, Zaire, Nepal, Indonesia, Argentina and Afghanistan and others. Several of these plants are in danger of extinction, particularly from traditionally rich, easily accessible forest ranges.

The exploration for medicinal plants has been directed mainly for identification of superior sources of phytochemicals or for new drugs rather than on collection of genetic diversity. Another major gap is the near absence of catalogues of genetic

stocks maintained by national institutes.

In recent years, the National Bureau of Plant Genetic Resources, New Delhi has extended exploration to medicinal plants. The studies carried out at the Bureau on Opium Poppy, Syllium, Senna and Rauvolfia serpentina were summarized.

It is suggested that a survey be made on the availability of genetic stocks and priorities for individual crops and regions can be drawn on the basis of occurence of maximum diversity. This survey would provide a basic working paper for crop exploration for five to ten years. It is also necessary to identify institutes responsible for evaluation, cataloguing, supply and maintenance of these stocks. It may be placed on record that exploration and evaluation of genetic stocks in medicinal plants would need constant support of a well equipped chemical laboratory at each participating centre.

(v) Discussion

On SASTRAPRADJA'S paper: KHIDIR asked if Hibiscus sabdariffa was used as a fibre or beverage. SASTRAPRADJA said as a fibre. STEELE asked where a supply of winged bean could be obtained. SASTRAPRADJA said from Thailand. LEÓN asked how the yeast for fermenting cassava was maintained. SASTRAPRADJA said by mixing with rice flour and drying.

On PALMBERG'S paper: MORANDINI said several tree species could be used for fuel. He was pleased to hear that the IBPGR was supporting some aspects of forestry genetic resources.

On VAN SLOTEN'S paper: MENGESHA said taro was widely used in Ethiopia and showed great diversity. Representative material should be preserved. ROBERTS said that varying views about the nutritional value of leafy vegetables were a question of lack of determinations rather than under-estimates. Protein was easily determined but vitamins etc. were difficult.

On GUPTA'S paper: SYKES asked if work on drug plants was being done in India. GUPTA said some drug plants are grown and exported. Programmes were being carried out all over India.

General discussion: KHAN asked why rangeland and forage crops were not being considered in this session. WILLIAMS replied that time limited the programme and also the IBPGR had already agreed to work on forages. DENTON said that in Nigeria local horticultural genetic resources were not threatened because people preferred the indigenous varieties to foreign ones. Nevertheless, collections of cassava, leafy vegetables and jute had been made. THOMPSON said Cannabis sativa was used in Jamaica to treat eye diseases; some cucurbits were used against cancer. Large numbers of medicinal plants are not protected. He would welcome assistance from the IBPGR. PRECOTT-ALLEN commented that trees and medicinal plants were suitable for in situ conservation. Herbs, leafy vegetables and spices made staple foods more palatable. SIMMONDS observed that man made use of 10 to 20 important crop plants and perhaps 100 forest tree species. We still do not know the potential value of others among the thousands of species. This in itself was a strong argument in favour of in situ conservation. MEHRA said that in India some medicinal plants were threatened

by over-collection by local people. CARDENAS-RAMOS spoke of the traditional use of medicinal plants by 80-90 percent of the people in Mexico. There were 300-400 species that should be identified and examined by the biochemist. MENGESHA said that Ethiopia offered tremendous resources of medicinal plants. MELA said work had started on Ethiopian medicinal plants but it was not given high priority. In situ conservation would be considered. DENTON thought information on the use of medicinal plants should be collected from local families with the help of the IBPGR. WILLIAMS said this type of work should in principle remain a national responsibility. KHIDIR said the medicinal plants of the Sudan were under threat; a small unit had been formed to start collection. GUPTA observed that in India medicinal plants used in the pharmaceutical trade were threatened with loss and traditional medicinal plants were being over-collected. IBPGR should support programmes to deal with these situations. MENGESHA voiced a similar wish. WILLIAMS replied that the IBPGR could not undertake all work. Its mandate was for food crops; it had been broadened to include some forestry and it was unlikely to expand in further areas quickly. FRANKEL suggested that the IBPGR should consider setting up a Working Group to look into the problems. OLEMBO thought FRANKEL'S suggestion a good one. Medicinal plants and leafy vegetables were very important and their collection and conservation should be started in a small way. WHITE referred back to forest species, mentioning the potential value of Acacia, Prosopsis, Eucalyptus and Leucaena. Many requests for seeds of Leucaena were received. PALMBERG was aware that Prosopsis could be a terrible weed but it was not a problem in the arid and semi-arid zones. The limited manpower of the programme would not allow Leucaena to be included.

2.10 OPEN FORUM

Presided over by O.H. Frankel

(i) The utilization of germplasm collections — O.H. Frankel

For most of the major crops, collections are now the main repositories for genetic resources still in existence. How we manage the collections is therefore of crucial importance. Fifteen years or so ago, the idea was to collect everything but size is now seen to have disadvantages. The problem is how to contain collections. What follows refers to domesticates, not wild species for which the situation is quite different. A collection should be as representative as possible and yet not exceed manageable limits. These are determined by the costs of facilities, regeneration, distribution and the like. Evaluation is the most expensive of all. There is also a psychological cost. A well-contained collection without redundant duplicates would encourage use. The most obvious measure by which to reduce size is to reduce redundancy. This is relatively easy with vegetatively propagated crops but not so with seed crops, the ones considered here.

The problem is to find associations among entries. Evidence would come from place of origin, name of variety, characterization and evaluation data and electrophoretic surveys, all of which could be examined by multivariate analysis. All of this information would give a good deal of direct evidence of presumptive genetic similarity at least. This list of characters does not include disease resistance and so forth but it has to be remembered that at the time of collecting, selection is made anyway. Why not select after you have explored and collected as well? A.H.D. Brown and I suggest that there are three possibilities (always within the circle of nearly identical entries): (1) random elimination; (2) bulk elimination and (3) within sample reduction. As regards probabilities of loss of genetic information

Brown found a substantial potential loss in random elimination but the lowering of allelic frequencies is much smaller in bulking or in reducing the size of individual entries. So a priori, bulking appears as the most attractive way of dealing with redundancies.

The graph prepared by Brown (Fig. 1) shows how much you can reduce a bulk sample without major loss of genetic information. It shows that when dealing with a single locus (say disease resistance) you have very little chance of finding it whatever percentage of the population you retain. In contrast, when you deal with 100 loci, even 20 percent of the original sample includes a large proportion of the allelic population. To generalize, you could for example keep 10 percent of a bulked sample made up of 20 entries each with say 1,000 seeds. This realization should give you the courage to contain the size of your collections and so reduce enormously the work of maintenance and evaluation.

If you accept Marshall and Brown's thesis that you are after the locally selected alleles, you will not lose them because if you collect taking a number of samples, something like a frequency of five percent will still appear in a bulked sample of ten. You cannot miss an allele if there is good recognition possibility.

To conclude this introduction, I am quite convinced that collections will be much more used if they are smaller and if the user has confidence that different entries mean something different in genetic terms.

(ii) Discussion

FRANKEL invited comments from those critical of the idea of bulking. STEELE was not opposed to it but gave an example of a case for which it might not be suitable. One cultivar of cowpea among 8,000 tested had been found resistant to bruchids. It was a single gene behaviour and saved 30 percent of the yield in Africa. If samples had been bulked, this rare allele could not have been recovered as tests of single seeds were not possible. HUAMÁN commenting on this observation thought that bulking might be done on a geographical basis to capture rare alleles. On a different point, he said that large genebanks had many duplicates even of seed samples as well as vegetatively propagated material; for instance at Braunschweig (F.R. Germany), Sturgeon Bay (USA) and CIP. The solution was to produce catalogues in which all accessions with the same provenance and collector's number should be put together. MEHRA observed that there were many microcentres of genetic diversity in India and it would be difficult to bulk on a geographical basis. In reply to a query about the number of plants to collect from, FRANKEL pointed out that sampling must be considered separately from the question of dealing with samples once they were in a collection. It was then a case of considering how much of the allelic composition is lost by bulking or any other means of reducing redundancy. As regards redundancy between collections he has never thought this should be avoided. Although happening by chance, it was still useful and different from duplications within a collection. He could not answer GIACOMETTI'S question about when to start reducing the size of collections held in the 39 genebanks of Brazil. About cowpea, it was quite obvious that if one very outstanding gene is represented in a single accession, you would not bulk. The premise was that there had to be a degree of evaluation of individual entries before bulking. SINGH fully supported what FRANKEL had said but a few qualifications were needed. BROWN'S graph was too simple. With a particular

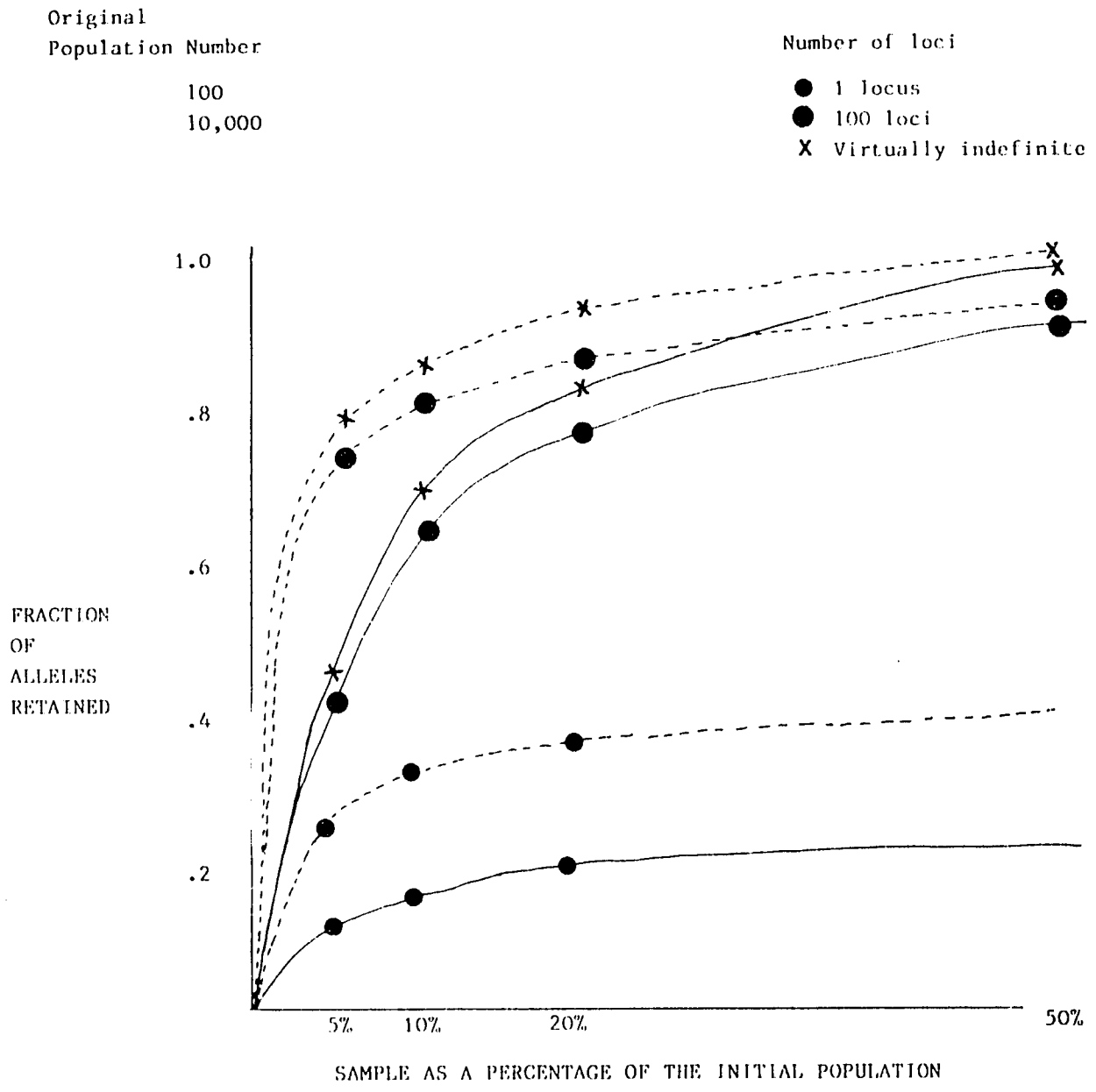

Fig. 1. Approximate lower confidence limit (95%) for the number of alleles retained (8 = 1)

size of sample, the inbreeding coefficient had to be considered. Multiplication was not resorted to too often, maybe every 20 or 50 years. If the graph represented an infinite number of generations then it needed modification. Multiple alleles and linkages had not been considered. To obviate these limitations to a certain extent, we know that if an equal number of seeds is collected from each plant in a population, the samples being small, this increases the effective population size very much. These simple tricks do increase the effectiveness of maintaining alleles through generations. With an outbreeeder, if the population size is small, if possible biparental matings may be resorted to. They will give high efficiency and effectiveness. ROBERTS favoured FRANKEL'S suggestions but returned to STEELE'S example. Although an allele may be present with a frequency of five percent, there are some characteristics, particularly physiological ones, that cannot be examined on a single seed basis. A high frequency of the allele in the accession is essential. FRANKEL said any plant breeder would agree that it is always easier to discover characters in progenies than in single plants. All the same, in many instances bulking could be a very useful device and it will be inevitable if collections are to be used.

(ii) Duplication of collections J.T. Williams

With the technology for the maintenance of seed collections now established, duplication of collections is largely a matter of organization.

In designating centres to old material for long-term storage, the IBPGR had had to accept what was available. There was a shortage of storage facilities and those that were used were often not of the highest standard. Funds have been available for upgrading facilities but the IBPGR had not had in several instances assurances from institutes and governments of a willingness to meet the commitments required for a genetic resources centre.

Duplication of a collection is an important issue relating to safety. A factor that had to be taken into account was size of sample. For long-term storage there must be adequate seeds; a sample of 100 was not enough; for some crops the number was nearer 12,000.

As Sir Otto Frankel had said, duplication could be treated in the same way as luggage deposited at a railway station. Sub-samples were put into a box and sent to another genebank. This was satisfactory so long as the primary centre was careful to monitor viability and say when rejuvenation was necessary.

Although the designation of base collections had been slow, it was now going ahead and by 1985 a skeleton structure would have been built for most of the major crops: cereals, grain legumes and vegetables. The movement of materials was slow but that was a fact of life and had to be lived with. Individual parts of the global network belonged to nations, international centres and a diversity of organizations. The IBPGR could see as far as possible that standards were maintained but it could not direct operations.

It was sad to note that in a number of instances standards had not been maintained and simple principles of duplication had not been met. However there were bright spots. Representatives of the institutes that hold the world wheat col-

lections could say how they had exchanged collections and ensured satisfactory duplication.

Replication is an important activity concerning the future of the material and its availability to all.

(iv) Discussion

FRANKEL asked if WILLIAMS would say whether or not his Secretariat took responsibility for arranging duplication and how many holders of base collections have made arrangements for duplication. WILLIAMS said the Secretariat does: about a third had been duplicated to date but remember the designation of base collections only started three years ago. Either genebanks were not available or not willing to hold duplicates, these were the problems. Some would hold a box of samples until another genebank received them but did not wish to be involved with multiplication, documentation etc. Changes were happening and in ten years circumstances might be better. FRANKEL thought national collections should also be duplicated. Some were very rich like those in Canada and India. Did they make arrangements for duplication? It was an important question in view of the possibility of loss. MEHRA said that India duplicated rice in IRRI. STANWOOD spoke of practical difficulties. Several large collections were held at NSSL in boxes e.g. IRRI's 17,000 rice accessions. If they were processed into the laboratory under NSSL's procedures, it would cost about six years of the Laboratory's funding at the current annual rate. Hence the reluctance to accept duplicates. FRANKEL asked for more remarks about difficulties. MANRIQUEZ said the emphasis in Peru was on maintaining collections in individualized forms more than in compound forms. Each ecotype could be used for separate objectives. Duplication was at regional centres. These sometimes had difficulties with maintenance and samples were replaced from the national genebank. It was of primary importance to have a back-up system. WILLIAMS and FRANKEL concluded that the "box model" was by far the simplest and safest to use for duplication. ROBERTS agreed. However, to know what was happening in the box, records should be kept of what is happening at the genebank and fed back to the home source. Even Fort Collins was known to have electricity failures! These data were required in relation to a check on viability.

(v) Utilization of collections: discussion

In discussing the utilization of collections, FRANKEL asked participants to concentrate on problems and difficulties. Good use is made of some collections but not of others. What are the constraints that limit use? At present we are in the heyday of genetic resources but it may be that in a decade or so politicians and administrators will want to economize and question the usefulness of collections. This Conference will have been worthwhile if it can make useful suggestions for bringing collections into full use. SASTRAPRADJA said the constraint in Indonesia was lack of plant breeders. There was the equivalent of only 5½ breeders in the whole country. Questions were already being asked about the use to which collections were put. She would welcome cooperative porogrammes aimed at making use of the material. CHANG said USA, Japan and India all had rice collections before IRRI and made use of them. Dramatic benefits had accrued in the last two decades. Varieties with the semi-dwarfing gene from Japan now covered half the world's acreage of rice. IRRI had selected varieties for earliness, resistance to viruses, froghopper and other adverse factors. India tested its own collections and exchanged with IRRI; Sri Lanka was

using material for insect resistances and adverse soil factors such as iron toxicity. Both Bangladesh and Thailand were improving deep water rices and keeping quality for export. China was making use of cytoplasmic sterility for hybrids. Constraints were climatic e.g. low temperatures and deep water; quality, whether dry or sticky and linkages that were difficult to break. GREAVES said that selecting the provenance of seed lots was the main concern in forestry; it meant the difference between success and failure, not just improvement. Uncoordinated introductions around the world had led to loss of confidence in what could be done. However with correct species and the right seed provenance research can recreate confidence and reclaim infertile sites. Examples were quoted of successful experimental plantings in Uganda, Queensland and Brazil. GROBMAN thought collections were not used possibly because geneticists had not described their true potentials. Again, landraces were not as easy to use as advanced breeding lines. In maize and sorghum deleterious genes could be removed after two or three generations and "wild" material then used. Information about the ecological properties of collections should be obtained as well as about the evolutionary relationships of different populations. It was useful in maize to know the affinities of races for heterosis. In Peru, 250 races are being used. He thought that when populations had not suffered environmental stresses, they could be pooled but when subjected to such stresses they should not. In the latter case, gene frequencies would differ. At CIAT, useful lines had been found in collection of beans, cassava, legumes and grasses. INGOLD expressed the view that countries fell into two categories from the viewpoint of collections. If genebanks were not used in developed countries, this was because they were not needed; direct exchange of material took place between plant scientists. If they were not used in developing countries, this was mainly because the infrastructure to benefit from collections was not built. LOPEZ said that at his institute in Colombia, they had selected 214 new varieties as a result of work during the past quarter of a century. Storage of accessions was their major problem. WALDMAN said that thought should be given to breeders' material. What should be kept - parental lines, hybrids, end products? This was a crucial problem for storage and energy conservation. AMARAU spoke of the value of collections for teaching purposes. FRANKEL concluded the discussion with the comment that much more prominence should be given to "utilization" if another Conference was held.

(vi) <u>The question of an international agreement or convention for crop genetic resources</u> O. Brauer

In his address of welcome, Dr. Bommer said "....The second question is related to the responsibility which had to be clearly established for those possessing the genetic resources and who should make them available to others to be used in plant breeding efforts. In this latter field scientific interest is certainly an important motivation for establishing the responsibility. But this scientific interest can change under various circumstances such as the change of governments and their public support or the change of department heads and their scientific specialization. We have to ask for those who possess major collections of genetic resources (either through natural heritage or through efforts made in collection) whether there should be an obligation established by some kind of an international agreement or convention, to ensure the maintenance of the genetic resources and its free exchange to all interested in it because of its international importance for future agricultural development."

Many countries with an interest in genetic resources think that FAO or IBPGR or both have genebanks when, of course, they do not. Material is held by institutions. The day may come, say in a decade or so, when financial support is withdrawn from the IBPGR in the belief that enough has been spent on collecting, storing samples, documentation and the like. What would happen then? Sir Otto had remarked in private that if finance is withdrawn, no institute or other organization will support a genebank. Can we find an agreement among nations to keep these materials and make them freely available? I will leave the question open but in doing so remind the audience that the way to get support is to utilize the collected material. Governments, even scientists, are bound to wonder in ten or twenty years time what benefits have been derived from collections if no-one can say what percentage of the material has been put to good use.

(vii) A lawyer's reflections on some problems of genetic resources conservation and exchange — R.H. Demuth

Sir Otto Frankel introduced Mr. Demuth saying that as the first Chairman of the IBPGR and a lawyer by training, he was well qualified to look at the problems of genetic resources from the viewpoints of both the technician and the administrator.

The Quinquennial Review team which reviewed the activities of the IBPGR during its first five years on behalf of the Consultative Group on International Agricultural Research (CGIAR) included among its recommendations that the Board should explore, in consultation with FAO, the idea of an international legal framework that would secure free access to collections. Similarly, a report to the U.S. President in January, 1981, entitled "Global Future: Time to Act" - a follow-up to the earlier "Global 2000 Report" - produced by the U.S. State Department and the Council on the Environmental Quality contains a recommendation that the U.S. Government should explore the desirability and feasibility of an international agreement on the preservation of agricultural genetic resources as a means of raising the visibility of and support for the IBPGR and other cooperative international germplasm programmes. The statement this morning is directed to the issues raised by these two recommendations.

Mr. Demuth started by saying that, from a strictly legal standpoint, the IBPGR and its operations are a nightmare. The IBPGR was created as a voluntary association without any real legal standing and without reference to any specific system of law - and it was created by, and is responsible to, the CGIAR which itself is a similar voluntary association with no recognized legal personality of its own. Yet, despite this legal fuzziness, the CGIAR has functioned very effectively and so has the IBPGR. The reason is that both have been supported by a remarkable degree of voluntary cooperation from a multitude of institutions and individuals all over the world. Indeed, in the 6½ years during which Mr. Demuth had the privilege of serving as the Chairman of the IBPGR, he could remember no significant request for cooperation made by the Board which was refused, whether it was addressed to a government, an international agency, or a national research organization. It is that cooperation which made possible the substantial progress achieved by the IBPGR in a relatively short period of years.

A few examples are relevant. The basis of all our documentation work is the use by genebanks within the Board's network of agreed lists of descriptors and descriptor states. These lists have been drawn up by various groups - sometimes by one of the IBPGR crop advisory committees, sometimes by a regional committee, or a regional

centre, such as CATIE, sometimes by an ad hoc group assembled by the Board. However formulated, once such a list has been approved and published by the Board, its use by the curators of collections, while not legally mandatory, has, in practice, been widespread. As a result, a common language is being developed for use by scientists to identify their need for materials with specific genetic characteristics, and by curators to determine whether their collections contain such materials.

Similarly, the genebank network being developed by the Board has as its key elements a number of centres which have been designated by the Board, after appropriate consultation, as responsible for maintaining major base collections of the germplasm of specific crops. As of the end of 1979, there were 16 centres in both developed and developing countries which had agreed to accept such responsibility, all on a voluntary basis. In toto, over 60 national, regional and international centres have agreed to participate in the Board's network, with most of them assuming responsibility for maintaining medium-term active collections of one or more priority crops.

Mr. Demuth did not wish to suggest that the Board should continue for the indefinite future to operate with the same informality as had characterized its past operations. As the IBPGR programme grows, there would be great merit in tightening up the agreements which the Board makes with the various centres within its network by spelling out in some detail the obligations which the centre is expected to fulfil with respect to conservation, regeneration, chracterization and evaluation, documentation, exchange of information and materials, creation of links with other centres, submission of periodic reports and the like - and also the benefits which the centre can expect to receive, whether directly from the Board or as a consequence of its membership in the Board's network. This would involve the negotiation of individual agreements tailored to the particular needs and basic policies governing the activities of each centre. For example, such an agreement with the U.S. National Seed Storage Laboratory at Fort Collins, Colorado, which is a facility solely for long-term storage of a variety of crops, which is neither so located nor so equipped as to enable it to regenerate itself many of the seeds which it stores, and which is an agency of the Federal Government subject to the rules and regulations and priorities of that government, would have to be very different in its requirements from a comparable agreement with the International Rice Research Institute in Los Baños, Philippines which is a relatively autonomous international entity, undertakes both long-term and medium-term storage of rice, has an active working collection as well, and in fact plays a leading role in the global programme for the conservation and use of rice germplasm. Thus, the course suggested would necessarily put a substantial burden on the IBPGR Secretariat. It would have the great advantage of assuring that all participants in the IBPGR programme would know with some precision what their role is and of setting performance standards which the Secretariat could then monitor. It must be emphasized however, that the agreement with each centre would have to be individually fashioned to reflect what that centre is able and willing to do, thus preserving the voluntary character of the cooperation which, as indicated, has been an essential element of the IBPGR's success.

The creation of an international legal framework for genetic resources activities is an entirely different matter; to be blunt, it is an approach about which the speaker was sceptical. Essentially, this is because there is so much variety in the situation of the various centres involved in the IBPGR network that negotiation of

a meaningful code to govern the activities of all of them would be a difficult, if not indeed an impossible task. Even if such a code could be agreed upon, the negotiations would necessarily be very time-consuming - and while they were in process, it seems likely that centres would be reluctant to assume new responsibilities on behalf of the IBPGR, thus destroying the momentum which the Board has achieved and increasing the risk that irreplaceable genetic materials might be lost. Finally, the very existence of a legally binding international code, assuming one could be negotiated, would be likely to impair the voluntary character of the co-operation which has been the basis of the Board's success. These substantial drawbacks to any attempt to create an international framework for IBPGR's operations are not counterbalanced by any prospective benefits that cannot be realized - more quickly, more economically, and more efficiently - through a series of agreements with individual centres of the kind proposed.

The international agreement envisaged in the U.S. Government report, "Global Future: Time to Act", appears designed less as an operational code than as a mechanism for obtaining increased donor support for existing programmes, for additional regional collection and storage efforts and for on-site living preserves. If these objectives could be advanced by a new international agreement on the subject, we should all favour the effort. But again, we have an existing mechanism - the CGIAR - which has been extremely effective in mobilizing large-scale support on the basis of voluntary cooperation among donor governments, for international agricultural research programmes, including the programme of the IBPGR. From a funding level of about $10 million in 1971, the CGIAR has succeeded in moving to a funding level of $140-150 million for 1981. Indeed, the growth of the CGIAR is a success story that is almost unique in the annals of development assistance. There is no reason to believe that a formal international agreement to support international and regional genetic resources centres would result in more funds for this purpose than are available through CGIAR channels. To the contrary, abolishing a proven mechanism, which has the unstinting support of donor countries from around the world, in favour of a new international agreement designed largely for the same ends, would not necessarily be the course of wisdom.

The same considerations apply to activities in which the IBPGR does not participate. It is important that such activities be conducted in accordance with the basic principles laid down by the IBPGR - namely, that duplicates of all plants collected be left in the country of collection and that there be a free exchange of information and materials. Both FAO and the IBPGR have enunciated these principles over and over again - and they are coming to be accepted as the appropriate standards for international conduct. The IBPGR could do more, perhaps, by agreeing to receive complaints from individuals or agencies who have been refused access to genetic resources held in another country and seeking to resolve the difficulty. Mr. Demuth was not clear what an attempt to negotiate an international agreement would accomplish - for a country unwilling to accede to these principles in practice would not be likely to agree to a treaty incorporating them - and, if it did sign such a treaty, might well fail to abide by its terms. What is needed is a general international understanding, perhaps supported by a declaration adopted by the FAO conference, not a formal international agreement.

(viii) Discussion

GIACOMETTI appreciated DEMUTH'S proposal. Brazil contained wild relatives of Cacao, cassava, rubber, pineapple and groundnut. Requests for permission to collect have been supported by him. On requesting material from others, the government authorities were not getting it and this was causing difficulties e.g. African oil-palm germplasm, black pepper, castor bean, etc. Such a problem could be dealt with under an international agreement. DEMUTH said the Board's good offices could be used for this sort of problem. Failure to comply with a specific request could mean denial of access to the Board. CHANG informed members on a recent visit to China he had stipulated free access of materials as a condition for a million dollar grant from the Rockefeller Foundation for a storage facility. MEHRA said that he had experienced difficulties in getting materials. He thought the Board should consider forming a Working Group to include representatives from countries that hold genetic resources to consider problems. Concern may be felt in these countries that materials are being exploited by trade channels. GROBMAN said all expeditions were welcome in Peru provided duplicates were left. This had built up local collections, good cooperation and exchange of samples. VAN DER BORG said general opinion voiced to the EEC genetic resources programme was that material was difficult to get from the main centres around the world and so was information. This had been shown by the poor response to a questionnaire in connection with the World Report for Allium. He made a plea for freedom of information exchange. FRANKEL concluded from the relative lack of discussion that delegates were fairly well satisfied with the present informal procedure. Would country representatives express their views? He asked DEMUTH to explain the alternatives. DEMUTH said there were three: (1) Loose agreements between IBPGR and countries coupled with an enunciation of principles; (2) A more precise series of individual agreements with designated centres, defining materials and responsibilities and specifying free availability of materials and information; (3) An International Convention as suggested by BOMMER and BRAUER. The country delegates informally indicated the preference by a show of hands. The voting was 19:1:6 for 1, 2 and 3 respectively. GROBMAN said he voted for Alternative 1 not because it was the best but because governments could not operate a legal system in agreement with the IBPGR, an unofficial organization. Such an agreement would have to be within the UN system. FRANKEL concluded that there was overwhelming support for the current system even though in some instances people failed to get the material they requested. WILLIAMS added that much of this material was industrial/commercial germplasm and the difficulties in exchange of food crop materials were not great.

3. CLOSING SESSION

Chairman: Dr. L. Åhre

Dr. Åhre opened the Session by thanking those who had submitted proposals for doing so and the Drafting Committee for finalizing them ready for consideration. He reminded participants that the recommendations from the Conference would be limited to technical matters and that financial aspects should be taken into account so that important needs were covered. It was then agreed that the proposals should be taken singly for discussion. The following are those that were approved.

3.1 RECOMMENDATIONS

Concerning collecting:

1 - that the IBPGR should request the FAO, UNDP and IBRD (co-sponsors of the IBPGR) and other agencies always to make collection of endangered local species and landraces an activity within crop improvement projects.

2 - that more collecting missions for wild relatives of cultivars should be carried out.

3 - that collecting within mixed plantings and multicropping systems should be done in a way that allows the preservation of combinations of interest.

4 - that as different sampling techniques must be used for different crops and different environments, a range of realistic collecting techniques should be developed to meet the needs of collectors.

Concerning forage crops:

5 - that an action programme to explore, collect, conserve, characterize, evaluate and use forage plant genetic resources should be initiated jointly by the IBPGR, FAO and UNEP.

Concerning special crops:

6 - that genetic resources programmes should be encouraged to take responsibility for species of particular significance such as traditional and medicinal plants; and programmes with regional responsibilities should endeavour to become centres of excellence for them.

Concerning forestry:

7 - that emphasis should continue to be placed on forest genetic resources, particularly species used in arid and semi-arid zones for fuel and other tree species of wide social and economic importance or potential.

Concerning forestry (cont.)

8 - that countries and agencies responsible for reserves should consider whether or not additional areas are needed for special needs such as the conservation of wild relatives of cultivars, related weeds and the maintenance of genetic diversity within species.

9 - that guidelines should be set out for planners and managers of protected areas to advise them on measures that should be taken to conserve genetic resources and at the same time leave them available for use.

10 - that UNEP and the International Union for the Conservation of Nature (IUCN) should encourage *in situ* conservation in areas that can be used for educational, recreational and other purposes.

11 - that as a first step towards the establishment of a data bank for crop genetic resources maintained in protected areas, a comprehensive inventory of the wild relatives of crops should be compiled and other information essential for *in situ* conservation of plant genetic resources should be assembled.

12 - that an *ad hoc* committee consisting of representatives of FAO, UNEP, IBPGR, UNESCO/MAB and IUCN should be formed to advise on all aspects of the conservation of genetic resources in protected areas and to assist in the coordination of this work with the conservation of forest and range land genetic resources.

Concerning conservation and regeneration

13 - that additional cold stores should be provided to strengthen the international network of these facilities.

14 - that, as the study of regeneration has been neglected, the IBPGR should support investigations to determine basic principles so that standard methods can be developed particularly for tropical crops and cross-pollinated species.

15 - that centres holding large working collections should make the improvement of services offered to *bona fide* users a major goal.

16 - that the IBPGR should initiate a survey of seed dormancy in the wild relatives of cultivated plants and the techniques used to overcome it.

Concerning in vitro conservation

17 - that in order to expedite the use of *in vitro* techniques for conservation, research should be intensified on the following:

(i) the improvement of specific techniques for crops for which *in vitro* propagation has been developed to such a degree that it is now realistic to attempt to apply the techniques, or develop them more extensively, to material in genebanks.

Concerning in vitro conservation (cont.)

(ii) basic studies of crops with which little if any success has been achieved so far with in vitro culture and propagation techniques.

(iii) cryopreservation of all types of plant material with the aim of establishing first principles.

18 - that a small working group should be appointed to collate and disseminate information on in vitro conservation and to advise on training programmes.

Concerning evaluation and utilization:

19 - that work on the characterization and evaluation of germplasm in genebanks should be expedited and findings transmitted to the potential users of the germplasm as quickly as possible.

20 - that the IBPGR should stimulate work designed to transfer valuable characters of wild species into breeding lines of cultivated plants in order to promote the utilization by breeders of useful characters.

Concerning documentation:

21 - that international descriptor lists should be used as a basis for standardization and data bases should be open-ended.

22 - that passport data should always be sent to the recipients of sub-samples for each of which the key identifier should be the collector's name and number and the number given by the institute holding the sample; for a breeding line the key identifier should be the breeder's number and institute; for cultivars, the varietal name and name of the institute that bred it.

23 - that more emphasis should be placed on the improvement of information exchange between genetic resources centres and to the feed-back of information from users of plant genetic resources

Concerning quarantine:

24 - that all germplasm exchange should take place through national quarantine services.

25 - that setting up national or regional testing laboratories should be considered by governments to expedite the passage of germplasm through quarantine.

26 - that the establishment of third country post-entry quarantine facilities should be encouraged particularly for clonal crops and other specific crops and their relatives.

27 - that the investigation of pathogens and pests carried by germplasm, including those of wild species and wild relatives of cultivars, should be encouraged in national research institutes.

Concerning quarantine (cont.)

28 - that research initiatives should be taken in the use of *in vitro* techniques for "cleaning up" plant germplasm to meet quarantine requirements especially as regards viruses.

Concerning training:

29 - that support for the training courses at Birmingham University on the conservation and utilization of plant genetic resources should continue.

30 - that the IBPGR should increase the support for practical training which should be obtained when feasible at a genebank.

31 - that regional training should be arranged in order to widen participation and reduce costs.

32 - that the IBPGR should consider giving support for specialist short courses on computer usage in data management to include the use of standard software packages.

33 - that consideration should be given by FAO to the organization of training courses dealing with problems of plant quarantine.

Concerning publications:

34 - that the IBPGR should continue to issue manuals concerned with the practicalities of genetic resources conservation and should consider producing them in several languages to enhance their usefulness.

35 - that a book covering the topics discussed during the Conference should be published.

36 - that bodies dealing with plant genetic resources should take steps to promote public awareness of the need to conserve and utilize them for the benefit of mankind.

3.2 CLOSURE

Dr. Köhre informed participants that the approval of the series of recommendations concluded the official business of the Conference.

On behalf of the three co-sponsoring Organizations - FAO, UNEP and IBPGR - Dr. Köhre expressed appreciation to the Secretariat of the IBPGR for the very satisfatory arrangements that had been made for the Conference. He also thanked those who had contributed papers and the Convenors of Sections for their skilled guidance in leading discussion. A special word of thanks was given to the interpreters who had coped so efficiently with technical discussion.

Closure (cont.)

Dr. Kåhre expressed the opinion that one of the most welcome results from the Conference was the opportunity it had given for personal contacts. He wished participants continuing success with their genetic resources programmes and then formally declared the Conference closed.

APPENDIX 1

PROGRAMME

Monday
6 April 1981

0900	Registration			
0930	Briefing of Convenors			

PLENARY SESSION

1000	Opening	O. Brauer		
	Addresses of welcome:	D.F.R. Bommer	-	FAO
		R. Olembo	-	UNEP
		L. Åhre	-	IBPGR
1045	Keynote address	J. T. Williams		
	"International cooperation; the past decade and prospects for the next one"			
1130	Nomination of drafting committee	O. Brauer		

TECHNICAL SESSIONS

SAMPLING (Convenor: J.G. Hawkes)

1200	Principles of sampling	S.K. Jain
1230	Sampling techniques for seed crops	E. Porceddu
1430	Analysis of variability in cereals and its practical applications to the conservation of genetic resources	P. J. Murphy and J. R. Witcombe
1500	Sampling of vegetatively propagated crops	J. León
1530	Discussion	

CONSERVATION I (Convenor: R. Olembo)

1600	The prediction of seed deterioration during storage	E.H. Roberts and R.. Ellis
1630	Procedures for monitoring accessions during seed storage	R.H. Ellis and E.H. Roberts

APPENDIX 1
(Continued)

Tuesday
7 April 1981 (CONSERVATION cont.)

0930	Problems of storing recalcitrant seed during collection and conservation	E.H. Roberts and M.W. King
1000	Discussion	
	CONSERVATION II (Convenor: E.H. Roberts)	
1030	The importance of *in vitro* techniques in germplasm conservation	E. de Langhe
1100	Genetic stability in *in vitro* cultures	G.G. Henshaw
1130	Germplasm conservation *in vitro*: present state of research and importance of cryopreservation	L.A. Withers
1200	Discussion	
	CONSERVATION III (Convenor: H. Garrison Wilkes)	
1430	*In situ* conservation of genetic resources	R. Prescott-Allen
1500	Use of back-garden system and natural reserves for iso-climatic regeneration of germplasm samples in Hungary	L. Holly
1530	General principles of germplasm regeneration	O.H. Frankel
1600	Discussion	

Wednesday
8 April 1981

	GERMPLASM EXCHANGE (Convenor: R. Smith)	
0930	Principles and practice of germplasm distribution and exchange	R. Smith
1000	Safe and rapid transfer of plant genetic resources - a proposal for a global system	L. Chiarappa and J. Karpati
1030	Discussion	
	CHARACTERIZATION AND EVALUATION I (Convenor: N.W. Simmonds)	
1100	Principles of characterization and evaluation	N.W. Simmonds
1130	Principles of evaluation	S.K. Jain

APPENDIX 1
(Continued)

GERMPLASM EXCHANGE (cont.)

1200	Time-related problems in the evaluation of forest genetic resources	J. Burley
1430	Evaluation of wild relatives of crop plants	J.R. Harlan
1500	Discussion	

CHARACTERIZATION AND EVALUATION II (Convenor: J.R. Harlan)

1530	Evaluation of germplasm: a case for rice	T.T. Chang
1600	Evaluation and documentation of germplasm: Southeast Asian experience	R.B. Singh and N. Chomchalow
1630	The evaluation of potato germplasm at the International Potato Centre (CIP), Peru	Z. Huamán

Thursday
9 April 1981

0930	Germplasm evaluation at Gatersleben, DDR; the relationship between genebank and breeder	C. Lehmann
1000	Discussion	

DOCUMENTATION (Convenor: J. Warren)

1030	Information capture and the rapid feedback of results	J. Warren
1100	Genetic resources documentation: a progress report	C. Howes
1200	Germplasm documentation: the future	S. Blixt
1230	Discussion	

UNDER-EXPLOITED CROPS (Convenor: S. Sastrapradja)

1430	Minor crops in Southeast Asia	S. Sastrapradja
1500	Genetic resources of fuelwood tree species for the improvement of rural living	C. Palmberg
1530	Changing priorities in genetic conservation: leafy tropical vegetables	D.H. van Sloten
1600	Genetic resources of medicinal plants	R. Gupta
1630	Discussion	

APPENDIX 1
(Continued)

Friday
10 April 1981 OPEN FORUM (Presided over by O.H. Frankel)

0930	The utilization of germplasm collections	O.H. Frankel
1000	Duplication of collections Utilization of collections: discussion	J.T. Williams
1030	A lawyer's reflections on some problems of genetic conservation and exchange	R.H. Demuth
1130	Discussion	

PLENARY SESSION

(Presided over by L. Åhre)

1430 Closing session: conclusions and recommendations

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APPENDIX 3

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