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State, use, problems of *ex situ* plant germplasm collections ***

1. Introduction

Information on the history of plant genetic resources conservation and their use can be found on several reports, catalogues and newsletters published by different institutions (FAO, IBPGR, IPGRI, and other CGIAR centres). Recent development in the maintenance, management and sustainable use of genetic resources and biodiversity, have suggested to some scientists and international organizations, to publish special issues on this subject (Pistorius, 1997; Swaminathan, 1999).

Plants have travelled, during human migrations and along the ancient caravan routes, from continent to continent. Moving from the Old to the New World and *vice-versa*, they have made many important contributions to the agricultural and eating habits around the planet (FAO, 1959).

Movement of plants from place to place and from people to people implies the use of germplasm as a food but also for improving agricultural production and for increasing diversification. Starting from the beginning of agriculture man has stored plants and seeds from one cycle of cultivation to the next in different ways, some of which are known to us and are used until today. Storage of germplasm took place also during migration. As agriculture progressed and human population grew up, the need to store plants and seeds *ex situ* increased and involved even longer distance and lapses of time than a simple break between seasons of cultivation or time needed to migrate. In a broad sense, *ex situ* conservation of germplasm is a practice that man has used since the beginning of agriculture, to expand culti-

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vation and/or to colonize new lands and to ensure spreading of agriculture around the world.

This paper aims to trace an historic profile of *ex situ* plant germplasm conservation with the main emphasis on the most relevant aspects related to protection of genetic diversity and its use for agricultural development.

2. History of ex situ plant germplasm conservation

From the beginning of agriculture, farmers have domesticated some hundreds plant species and within them genetic variability increased thanks to migration, natural mutations and crosses, and unconscious or conscious selection. This gradual and continuous expansion of genetic diversity within crops went on for several millennia, until scientific principles and techniques influenced the development of agriculture. This happened at the beginning of the 20^{th} century, when Mendel's laws were used. Spreading of new and more productive crop varieties, but genetically less heterogeneous than primitive populations, paradoxically started the well-known process of "genetic erosion".

In fact, in the 1920 and 1930s, N.I. Vavilov and Harry Harlan began to notice that traditional crop varieties, or landraces, were being lost from cultivated fields around the world. Since then, scientific efforts to conserve plant genetic diversity focused also on collecting material and placing it in *ex situ* storage.

For the sake of presentation, we have divided all of the efforts made by man on the *ex situ* germplasm conservation into the following steps:

— Conservation and use of crop germplasm before the 1967 FAO/IBP Technical Conference.
— Plant germplasm by FAO (IBPGR, Global System), IPGRI, and the Convention on Biological Diversity.
— *Ex-situ* collections and genebanks: size, place, state, distribution, and improvement of the system.

2.1. Conservation and use of crop germplasm before 1967 FAO/IBP Technical Conference

Before 1967, the international exchange of genetic resources functioned mainly among the network of plant introduction stations in Western Europe, USA, Australia, New Zeeland and Eastern Europe (mainly Soviet Union). There were only few genebanks (introduction stations) that exchanged genetic material. The most ancient and famous of them, with worldwide scope and enough evaluation facilities, were:

1. the All-Union Institute for Plant Industry, in Leningrad (now S. Petersburg), Russia (1920);
2. the Commonwealth Potato Collection at Cambridge, UK (before II World War);
3. the Collections for research programmes of the Rockefeller Foundation in the USA (1943);
4. the National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado, USA (1958).

Most of other seed banks were inadequate with regard to the later requirements of international agricultural research and most collections were considered erratic or unreliable. Moreover, most collections required frequent regeneration. In spite of these circumstances in which most of collections, of truly international scope, were held even in the 1950s, the overall picture on a regional level showed promising initiatives.

For example, in West Africa, plant quarantine regulations initiated in the late 1950s. Inter-African Phytosanitary Convention of 1954 was the umbrella of the Organisation of African Unity. Ghana established a Plant Exploration and Introduction Service. In 1960s, Nigeria and Côte d'Ivoire universities started collections activities. In Latin America, plant exploration started in 1950 and 1960s. Argentina started a National Service, Venezuela began maintenance of papaya and oil crops, Columbia focused on potato and grasses, and Costa Rica and Mexico on cocoa. Most of these activities had a strong interaction with the Rockefeller Foundation. In Asia, India started collection of pulses, cruciferous and forages in the late 1960s. Other collections were started by the Introduction Rice Research Institute (IRRI) in the Philippines and other countries. In Japan, in 1966 a National Seed Storage Laboratory was opened (Ito, 1972). Australia introduced much germplasm in the late 1960s, though a Plant Introduction Service, under the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), was established in 1930.

More relevant were the situation of North America and Europe and the first actions of FAO.

2.1.1. *North America*

Official government recognition of the importance of agricultural development first came in 1827, with the President John Adams. Only in 1898, a great impetus was provided through the creation of the Office of Foreign Seed and Plant Introduction. In the early 1960s, this office was renamed the New Crop Research Branch, with the headquarters located at the USDA Plant Industry Station in Beltsville, Maryland.

Owing to increasing demands for food and fibre and the industrialization of agriculture, crop improvement between 1900 and 1930 was mostly concerned with adaptation and yield factors of new varieties. However, even before the World War

II, breeders had problems related with disease resistance, quality, planting and harvesting methods, and reactions to plant protections or weed control practices. Therefore, germplasm material in US genebanks was mainly collected for short-term use in specific breeding programmes or for tests regarding agricultural diversification.

Once the demand of researchers was satisfied, the germplasm was stored at the National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado. This Laboratory was created in 1958 and was the first genebank with long-term seed storage equipment.

Advanced and well-organized collection of germplasm was coordinated by the Rockefeller Foundation in the USA in the 1940s and 1950s. A programme of improvement of basic crops, primarily maize, wheat and potato was started. This was called the Mexican Agricultural Program, and guided mainly by N.H. Borlaugh (1970 Nobel Prize). Later on, this program gave rise to the so-called "Green Revolution". Similar projects were carried out in Guatemala, El Salvador, Venezuela, Brazil, Uruguay, Argentina, Costa Rica, Cuba, Colombia, Peru and Chile, under the auspices of USA and American Land-Grant Universities. These collections, according to some scientists, formed the basis for a global network recommended by the FAO Panel of Experts in the early 1970s.

An important initiative of the USA was, then, the establishment of four Regional Plant Introduction Stations, at Ames (Iowa, 1947), Geneva (New York, 1948), Experiment (Georgia, 1949) and Pullman (Washington, 1952) and one interregional programme on potato. The stations were coordinated by the New Crops Research Branch, at the Agricultural Research Stations (ARS), in Beltsville. Thus, the NSSL at Fort Collins, Colorado was used for long-term storage and preservation of valuable plant germplasm propagated by seed, while the four smaller Regional Stations were used to maintain stocks for on-going breeding work.

2.1.2. *Europe*

In the 1920s the *USSR* went through a rapid industrialization of its agricultural sector. Vavilov made successful collecting expeditions during the 1920s and 1930s, not only in the USSR, but also in over 50 countries, in Asia, the Americas, Northern Africa, Europe and the Mediterranean basin. In all, 50,000 seed samples, mainly of wheat, rye, oat, pea, lentil, chickpea and maize, were collected and provided the basis for the establishment of modern genebanks in the USSR (Plucknett *et al.*, 1987).

Vavilov's ideas led him to the well known 12 Vavilovian centres of Crop Diversity. Plant breeding techniques progress after Vavilov's death urged the USSR to collect new material. In the early 1960s, Zhukovsky (from the N.I. Vavilov All-Union Scientific Research Institute of Plant Industry, VIR, Leningrad) complained about the lack of a continuous introduction of new material of cotton, maize, potato, bean, pumpkin, tomato, pepper, tobacco and groundnut. In fact, despite the Vavilov's efforts the institute's collections had considerable gaps (especially from Latin America, Australia, the Balkans and the Iberian Peninsula). In the 1960s, Zhukovsky was the only Russian contacting FAO for organizing expeditions to Latin America to introduce potato species resistant to virus degeneration, races of *Phytophthora*, nematodes, Colorado beetle, *Epilachna* and other pests (Whyte, 1958).

Germplasm activities were also initiated at the "Institute für Kulturpflanzenforschung", founded in 1942 at the "Tuttenhof domain", near Vienna. The first director was Hans Stubbe. During the World War II, in 1945, the Institute was moved to Quedlinburg and in 1946 to Gatersleben, (*German Democratic Republic*), in 1948 integrated into the "German Academy of Science in Berlin", renamed in 1968 "Zentralinstitut für Genetik und Kulturpflanzenforschung", (under the direction of Rudorf Mansfeld (1949/60) and S. Danert (1961/70).

In *Western Europe*, the need for an international central organization was quite general. An attempt to solve the problem of maintaining genetic stocks of potato species and varieties in their original integrity and free from diseases, was made by the British Commonwealth, which had established the Commonwealth Potato Collection (and by the USA with its IR-1, Inter-Regional Potato Introduction Project at Wisconsin). However, for several reasons (lack of up dated reports, breeders discarded not promising lines, etc.) it did not work (Hawkes, 1961).

This situation was typical for other crops. For example, in Italy, since the beginning of the century the improvement of *Triticum* species was based, by N. Strampelli and later on by others, on the collection and use of the wide genetic diversity available in landrace populations and also on distant germplasm (i.e. from Japan) (Scarascia Mugnozza and Porceddu, 1972; Porceddu, 1972). This European experience led to the conclusion that an international station could be the solution.

The European Society for Research and Plant Breeding (EUCARPIA) was established in 1956, in Holland. In the early 1960s it was the first organization to promote a collection network. It started off with a more generalist ecogeographical orientation (ecoregional genebanks). In 1962, the third Eucarpia General Congress, in Paris, emphasized the danger of loss of genetic resources. In 1966, Eucarpia delegates advised the European plant breeding Institutes to start a collaboration through regional genebanks on the continent.

The proposal resulted in the establishment of the following four sub-regional genebanks:

— North Western Europe. The bank was established at the former "Institute of Crop Science and Seed Research" of the "Federal Agricultural Research Centre" (FAL) at Braunschweig — Völkenrode, West Germany. Today, the genebank is part of the Federal Centre for Breeding Research of Cultivated Plants (BAZ). Dieter Bommer was the main initiator.
— Central and Eastern Europe. In the original plan, more than one genebank would be needed, for example, in Leningrad (already existing), Gatersleben

(already existing). Hans Stubbe (1942), O. Schwarz (1946), R. Mansfeld (1949), S. Danert (1961), C.O. Lehmann (1970), were the main actors.

— Southern Europe, including the Mediterranean region. The genebank was established at Bari, Italy. The main proponent was G.T. Scarascia Mugnozza.
— Scandinavia. The bank was established at Lund, Sweden, as a co-operative effort amongst the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden). The main proponents were Ebbe Kjellqvist and Stig Blixt.

Although none of the genebanks acted as sub-regional centres, they were all very active and successful. In 1970s, a special section of EUCARPIA, the Genebank Committee, formally linked to the section Wild Species and Primitive Forms was established (Hawkes was the first Chairman). There were annual meetings of members and genebank directors from Eastern Europe also.

2.1.3. *FAO*

In the 1950s and early 1960s, the other major actor in the conservation of genetic resources was FAO. Several World Catalogues of Genetic Stocks (wheat, rice, maize, barley) were set up in the late 1950s, while the FAO Plant Introduction Newsletter was seen as a key initiative and intermediary between breeders of the world. In the 1960s, the FAO Plant and Protection Service dealt with a continuous stream of enquires for samples of seed or vegetative material for use by breeders. FAO gene policies show a significant distinction between planning and actual programming. A strong call for immediate action in conservation, particularly for landraces and wild relatives, had already been made during the 10th Session of the FAO Conference in Rome, November 1959. The need for a truly intergovernmental initiative to streamline germplasm conservation and distribution was recognized during the 1961 Technical Meeting on Plant Exploration and Introduction, but was not worked out during later years. The dominance of breeders in the 1960s had a double impact: 1) conservation and use were closely linked; 2) storage in the first instance took place in industrialized countries and was tied to plant breeding institutes. Naturally, the history of FAO in collecting and exchange of germplasm is much richer of events.

The 1961 Technical Meeting on Plant Exploration and Introduction was the first initiative on a wide multilateral basis with the aim of extending initiatives in the field of plant introduction. For this purpose it was suggested that:

— National and Regional Introduction Stations had to be set up under the aegis of FAO;
— Exploration Centres should be built in regions of greatest genetic diversity and serve as centres for research on environmental interaction and add knowledge on landraces and wild relatives (Rudorf, 1961).

A pilot Exploration Centre was established in 1964, at Izmir in Turkey, which started under a joint project between the Turkish government, the UN Development Programme/Special Fund and FAO, acting also as Regional Centre for Afghanistan, Iran, Iraq, Pakistan, Syria and Turkey, organizing germplasm collection, conservation and evaluation. For some reasons the Izmir Centre began a successful work only later, in the middle of 1970s, and playing its main role at national level (FAO/UNDP, 1970; Frankel, 1985).

Moreover, a FAO-Unit of Crop Ecology and Genetic Resources, was established in Rome, in 1967, under the guidance of R. Pichel and E. Bennett.

2.2. Plant germplasm by FAO (IBPGR, Global System), IPGRI, and the Convention on Biological Diversity

2.2.1. *The 1967 FAO/IBP Conference*

The 1967 FAO/IBP Technical Conference on the Exploration, Utilization and Conservation of Plant Genetic Resources, held in Rome and organized by the International Biological Programme (IBP) and FAO, was an early occasion for a group of experts, later referred as the “Panel of Experts on Plant Genetic Resources”, to define a global strategy for the conservation of plant genetic resources.

In particular, the rising concern about possible genetic erosion of landraces and wild relatives due to modern agriculture, and the more general, increasing need of the agro-industry for a steady flow of new germplasm, convinced the members of the Conference to give more consideration to the generalist approach of conservation. New cold-storage techniques,[1] as developed in the 1960s, made long-term *ex situ* storage possible.

The alternative of *in situ* conservation was brought forward as well, although, this met considerable opposition from the scientists who emphasized the direct use of genetic resources in mainstream breeding programmes.

The scientific arguments for *in situ* conservation, as a complementary and as an alternative to *ex situ*, were mostly based on genecological premises. In any case, soon after the 1967 Conference, *in situ* conservation did not materialize and remained merely a theoretical dispute among breeders and geneticists. In general, the debates dealing with arguments on genetics, single-gene resistance versus polygenic resistance, socio-economic implications of single-gene resistance, genecological ideas and breeding strategies, led to conclusions in favour of *ex situ* conservation.

[1] There is a rich literature on research and results of methods on sampling, for conservation techniques in low temperature chambers, for engineering aspects of units for long-term conservation of germplasm, for methods of rejuvenation, and so on.

Notwithstanding the report of the Conference ("Genetic Resources in Plants - Their Exploration and Conservation") confirmed a general consensus on the need for more facilities and efforts for both *in situ* and *ex situ* conservation, in the following decade *ex situ* conservation became the dominant conservation strategy.

The 1967 FAO/IBP Technical Conference generated some important guidelines for the establishment of a global network for *ex situ* long-term conservation. The conversion of these guidelines into practical action took place quickly. A Panel of Experts on Plant Exploration and Introduction (established in 1965) generated a Plan of Action presented during the 1973 FAO/IBP Technical Conference on Plant Genetic Resources (Rome 12 to 16 March) and published under the title "Crop genetic resources for today and tomorrow" (Frankel and Hawkes, 1975).

The most important achievement of the Panel of Experts (which met 6 times from 1966 to 1975) was the formulation of basic arguments for conservation and use of genetic material. These were: a) that plant material was to be made available immediately and without restriction to all breeders requesting it and b) that genetic variability had to be maintained for future generations in long-term storage under conditions of maximum physical and genetic security (FAO, 1969).

During the Third Session of the Panel of Experts, in Rome, 1969 (FAO, 1969), the Panel pointed out a few regions in the world and the corresponding native crops that needed immediate attention: the Near East (wheat, etc.), the Sudanian zone of Africa (*Oryza glaberrima*, etc.), the southern and eastern Africa (forage grasses), Ethiopia (various local varieties), South and Central America (cotton, etc.), Southeast Asia (tropical fruits, etc.) and Oceania (yam).

This priority list was very broad and not practical. In its last formal meeting (March 1975), the Panel made a modified ranking. It recommended that the FAO first had to look for cooperation with the Germplasm Laboratory at Bari, to coordinate further exploration in the west and central Mediterranean regions. Ethiopia was given second priority, the third one being some tropical crops. These modified criteria illustrate a shift from a crop-oriented to a region-oriented approach.

A third important result of the Panel was a categorization of *ex situ* collections: base collections and active collections (genebank collections), and working collections (plant breeding institutions).

All these information led to plan in 1973 another joint FAO/IBP Technical Conference on Crop Genetic Resources. This differed from the one in 1967 in that it did not formulate scientific parameters for the conservation and use of plant genetic resources. However, the book that came out of it (Frankel and Hawkes, 1975), formulated practical action plans on: optimum sampling strategies in genetic conservation, sampling techniques for *ex situ* collections, methods of exploration in seed crops, vegetatively propagated crops and tree species, long-term storage of seed and pollen.

2.2.2. *Genetic erosion issue reaches the global scale*

Although the Panel of Experts had been very concerned about the negative consequences of genetic erosion, the issue received little public attention in the 1960s. The early 1970s, however saw an unexpected recognition of the issue as the world witnessed two serious consequences of genetic erosion. In 1970, a serious outbreak of "southern corn-leaf blight" in the USA reminded the scientific world that genetic variability was not always enough if the cytoplasm is entirely of one kind. In the same year, a catastrophic outbreak of "coffee rust" caused great losses in Brazil with higher coffee world market prices as a consequence. These cases provoked publicity on a global scale, generating a flow of information on other ongoing cases of genetic erosion. The Panel presented all these facts.

In 1972, within the agricultural community of the USA, the Agricultural Board and the National Research Council, with the publication of a report on the Genetic Vulnerability of Major Crops, attracted much attention, both within scientific and circles of agricultural non-governmental organizations (NGOs).

The key lesson of the Seventies is that genetic uniformity is the basis of vulnerability to epidemics and, more generally to biotic and abiotic stresses. The situation poses substantial challenges to scientists and to the nation (NAS, 1972).

Clearly the market wants uniformity. The irony is that the uniformity of crops encourages epidemics, can be synonymous of vulnerability and crop damage; but the scientist, not the market, tends to receive the blame.

However, although the report did not call for a complete revision of the agricultural marketing and can be synonymous of vulnerability and crop damage research system, but in offering facilities for scientists to prevent future disasters due to crop vulnerability, the committee advised the US Government to provide a complete "early warning" system, including: overseas laboratories to monitor exotic pests and to test American varieties against them; a quarantine service at the borders; a national monitoring committee and to provide the facilities for continuously maintaining gene pools. The need of accumulating and preserving genetic variability become necessary worldwide.

2.2.3. *The United Nations Conference on Human Environment (UNCHE, 1972)*

The UNCHE was held in Stockholm in June 1972. The influence of the ideas of the FAO Panel of experts becomes significant in the clear division of labour between *in situ* and *ex situ* conservation. It is stated that both are needed, but it becomes clear that genetic resources with an agricultural value had to be conserved in "national or regional genetic conservation centres" *ex situ*, such as the NSSL, USA or the VIR, USSR.

Wild relatives of crop species, on the other hand, would be maintained in their "national communities" (original environment) — *in situ* — for which the

UNESCO Man and Biosphere Programme was recommended to fulfil the important role.

To establish network of *ex situ* genetic resources, the UNCHE recommended "that the appropriate UN agency establish an international liaison unit for plant genetic resources" and "to provide the secretariat for periodic meetings of international panels and seminars on the subject; a conference on germplasm might be convened to follow up the successful FAO/IBP conference of 1967".

2.2.4. *Plans for a global network of genebanks*

After Stockholm 1972 and the 1973 FAO/IBP Technical Conference there was no direct impact in terms of more collection and storage activities. But, there was a rapidly growing network of several IARCs, belonging to the CGIAR network. The "establishment of a mechanism to encourage, coordinate and support action to conserve genetic resources and make them available for use" suggested during a meeting (1972) of the Panel in Beltsville, Maryland, was submitted to the CGIAR Technical Adviser Committee (TAC). This move had tremendous consequences for the position of scientists and Governments and International Agencies (FAO, first of all) in the conservation of genetic resources.

The plan embraced four elements:

— to create a Coordinating Centre (which later became the International Board for Plant Genetic Resources - IBPGR).

— to stimulate the establishment of genebanks in international centres already existing in developing countries (those already established were: IRRI, in 1960, CIMMYT, in 1966, CIAT, in 1967, IITA, in 1968).

— to establish genebanks in new international centres: the West African Rice Development Association (WARDA, 1971), the International Potato Centre (CIP, 1971), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, 1972). After 1972, to these organizations already existing, some others, like the International Livestock Centre for Africa (ILCA, 1974) and the International Centre for Agricultural Research in the Dry Areas (ICARDA, 1976) were also included in the network.

— to establish new "regional" genebanks in the Vavilovian centres of crop diversity; following an "eco-geographical approach", the centres would serve as a global division of labour in collection efforts.

While the scientific orientation of the FAO Panel embraced general incentives to conserve genetic resources, the institutional orientation of CGIAR was to extend its mandate in considering genetic erosion as a threat to the further development of the Green Revolution.

2.2.5. *The establishment of IBPGR*

The IBPGR, established in 1974, was as an institution formally integrated within FAO, but in practice it was autonomous. With IBPGR, genetic resources, rather than a mere seed introduction and distribution, became the new focus. The establishment of IBPGR accelerated the formation of a world network of genebanks. In this context, IBPGR had a precise but most important task: "to promote and assist in the worldwide effort to collect and conserve the plant germplasm needed for future research and production" (TAC, 1972). IBPGR replaced the activities of the Panel of Experts.

But "IBPGR might probably never have existed, or at least not in its present form, if FAO had not seen the need for conserving the genetic resources of crops and had not set up a Panel of Experts to provide the necessary scientific basis for this to be undertaken". IBPGR, on the other hand, offered FAO the financial support and manpower to build up and coordinate a new world network of genebanks.

IBPGR also managed to create and maintain standard criteria for the upkeep of collections. The institutions in the network that preserve genetic material on a long-term basis, form the core of IBPGR's international network. By 1984 it consisted of 40 collections in about 30 countries. Under the impulse on the preservation of their genetic resources and the need of establishing *ad hoc* structures, several developing countries were pushed to reorganize their National Agriculture Systems, including institutes or research groups for the attainment and maintenance of genetic resources collections.

The direct link with CGIAR implied that conservation strategies were defined as direct requirements for international agricultural research, in its need for landraces (and wild relatives) threatened of replacement by major crops, instead of those for local populations in developing countries. This "supply function" also implied that conservation tended to focus on major crops (most of all, rice, maize, potato, wheat and sorghum) and constituted a clear break with the FAO Panel of Experts initial view.

2.2.6. *Genetic resources and biodiversity as political and scientific issues and the establishment of the FAO Commission on Plant Genetic Resources*

The term "genetic resources" refers to the genetic information contained in the genes, the terms "biological diversity/biodiversity" encompasses all species of plants, animals and microorganisms (including ecosystems and ecological processes). While the genetic resources issue deals with "use" and "valorisation" aspects, the biodiversity issue also covers non-use and non value (such as ethical aspects). In the late 1960s and 1970s a group of 77 developing countries proclaimed a New International Economic Order (NIEO) in several fora, including

FAO. Other driving forces were Non-Government Organizations (NGOs) and the Rural Advancement Foundation International (RAFI). The NGOs constant lobbying within FAO against the North's dominance in the exchange and use of genetic resources and against the neglect of the rights and needs of small farmers, helped to shape the genetic resources issue as it stood throughout the 1980s. The International Coalition for Development Action (ICDA), renamed Genetic Resources Action International (GRAIN), was also an important source of information for NGOs. In the late 1980s, GRAIN published "New Hope or False Promise: Biotechnology and Third World Agriculture" (Hobbelink, 1987).

FAO was encouraged to establish the Commission on Plant Genetic Resources (CPGR), lobbied for the adoption of Farmers' Rights.

Scientists within CGIAR network tried to convince NGOs critics that the results from the research mostly benefited developing countries. RAFI and GRAIN reacted by saying that the CGIAR centres were the main driving forces behind the Green Revolution, the creators of monocrops and the main contributors to genetic erosion.

In 1995 the Commission, being involved in all aspects of genetic resources for food and agriculture, was renamed as "FAO - Commission on Genetic Resources for Food and Agriculture", with a current membership of 160 countries and the European Community.

2.2.7. *Genetic resources issues at the 20th, 21st, 22nd FAO Conferences*

During the 20th Conference, in 1979, a number of developing countries started to ask for information about the following issues (Esquinas-Alcázar 1989):

- Who owns the genetic resources collected with international money and stored in countries other than those in which they were collected? Who will guarantee their long-term security?
- What guarantee is there for continued free exchange of material in *ex situ* collections?
- How can countries benefit from the plant genetic resources that their farmers have produced, improved and conserved over millennia, as they currently lack the technical and financial capacity to use these resources for their own benefit?

Throughout the 1980s, FAO remained the principal forum in which developing countries tried to pursue their interest, which comprised: attempts to support the establishment within FAO of an international legal framework to set global standards and rules for the conservation and exchange of genetic resources, with the aim that genetic resources would remain available in the public domain.

During the 21st Conference, 25 November 1981, Resolution 6/81 was approved, which in its statement "e" emphasizes the lack of an "international agreement for ensuring the conservation, maintenance, and free exchange of genetic resources of agricultural interest contained in existing germplasm bank". It offered a window for FAO to get legal control over the CGIAR network.

Resolution 6/81 became one of the most hotly debated resolutions in the history of FAO. The genetic resources issue, having been a matter of discussion by experts during most of the 1970s, suddenly in 1981 received worldwide press coverage. NGOs were actively in favour, while industrialized countries, particularly the USA, UK and Australia heavily opposed the resolutions.

Nevertheless, the 22nd FAO Conference (1983) approved the proposal for an International Undertaking, which includes 11 articles and the establishment of the FAO Commission on Plant Genetic Resources (CPGR).

In spite of the limited support from industrialized countries to the Undertaking, the 22nd FAO Conference was considered a major victory for developing countries.

The first session of the CPGR took place in March 1985 and since then it has met every two years.

The discussion on the alternative FAO genebank network (point "2" of the Resolution 6/81) proved that idea of the physical genebank at the FAO headquarters central facility) was not feasible. The proposal of an international network of storage facilities, in the frame of CGIAR appeared more workable.

2.2.8. *Global System on Plant Genetic Resources (1983)*

The adoption of the FAO Undertaking on Plant Genetic Resources (1983) confirmed and strengthened this line. Art. 7 asked for a coordinated action of all institutions involved in the conservation of genetic resources to develop a Global System on Plant Genetic Resources for Food and Agriculture (Fig. 1), whose objective is: … ensure the safe conservation, and promote the availability and sustainable utilization of plant genetic resources for present and future generations, by providing a flexible framework for sharing the benefits and burdens (FAO, 1995).

The Global System is a means to effectuate the decisions of CPGR, but would also consist of *in situ* conservation areas and *ex situ* network of active and base collections, and form a core to strengthen FAO's political position in the collecting, conservation, evaluation and documentation, as well as the use of genetic resources. The CPGR and the Undertaking are the main support of the Global System. It falls into three main elements:

1. International agreements: a) Code of Conduct for Plant Germplasm Collecting and Transfer; b) Code of Conduct on Biotechnology and c) Basic agreements on genebanks;
2. Three network system (global mechanisms): a) the world Information and Early Warning System on Plant Genetic Resources; b) a network of *ex situ* genebanks (since 1994, including also the CGIAR collections), and c) a network of *in situ* and *on farm* conservation areas;

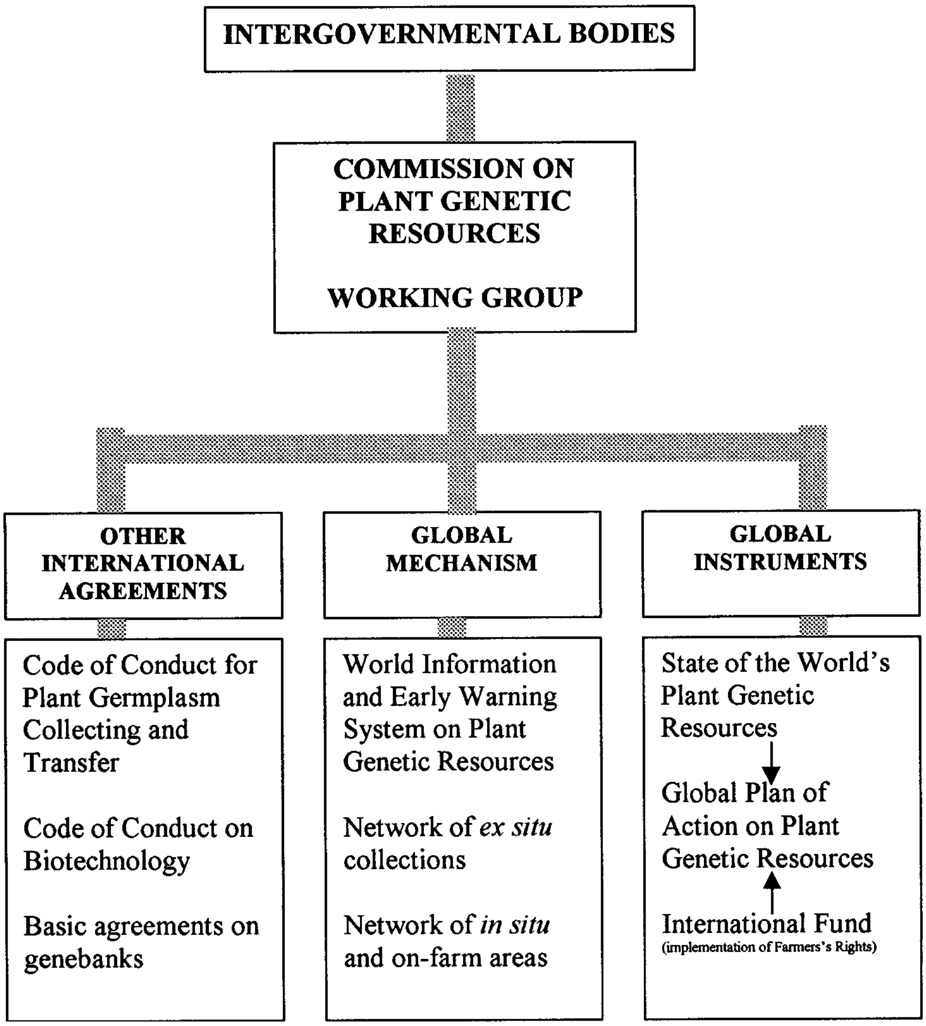

Fig. 1. The Global System for the conservation and utilization of plant genetic resources for food and agriculture (*source*: FAO, 1995).

3. Global Instruments: a) State of the World's Plant Genetic Resources; b) Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources For Food and Agriculture (GPA), and c) International Fund (FAO, 1996).

During the 1999 session, the "Commission on Plant Genetic Resources for Food and Agriculture" decided to complete the revision of the Undertaking by November, 2000. Moreover, during the 2000 session the Commission, due to the important development in biotechnology/genetechnology in relation to agrobiodiversity, decided to examine, in the 2001 session, a new text of the "International Code of Conduct on Biotechnology" in relation to the technical, legal, economic, social and ethical aspects of the use of biotechnologies and their positive and negative effects on genetic resources, taking into account the need to promote a balanced recognition of the rights of informal innovators (i.e. farmers rights) and of formal innovators (i.e. breeders rights) and the Cartagena protocol on biosafety aspects and other environmental impacts.

2.2.9. *The establishment of IPGRI*

In 1989-90, the CGIAR, following a proposal of its TAC, supported "the establishment of IBPGR as an international organization independently managed and preferably located near FAO headquarters in Italy". The International Plant Genetic Resources Institute (IPGRI), as successor of IBPGR, was formerly established on 9 October 1991, and ratified by the Italian Parliament in March 1994.

Up to now, IPGRI does not have its own research facilities but operates primarily as a catalyst and facilitator, contracting most of its research to partner organizations. In this way, IPGRI works to enhance strategic and adaptive research aimed at solving key genetic resources problems. IPGRI is also a specialized development Agency that provides direct technical support to national plant genetic resources programmes. Its way of working is based on strong linkages with many partners, a pro-active bottom-up approach and needs-driven objectives. The flexibility of this approach allows the Institute to respond to changing needs and circumstances and to take a broad view of biodiversity issues in general and the conservation and use of plant genetic resources in particular. The institute's partners are found at all levels of genetic resources work: national plant genetic resources programmes, research institutes, international and regional; organizations, universities, herbaria and botanical gardens, non-governmental organizations, the private sector, community-based organizations including farmers and women's groups.

2.3. *Ex-situ* collections and genebanks: size, place, state, distribution, improvement of the system

2.3.1. *Size of collections worldwide*

At present, over 6 million of accessions are stored *ex situ* throughout the world (Plucknet *et al.*, 1987; Scarascia Mugnozza, 1995; FAO-VIEWS database, 1996): some 600,000 are maintained within the CGIAR system, the remaining 5,4 million accessions are stored in national or regional genebanks (Table 1; Fig. 2). Nearly 39% are cereals, 15% of food legumes, 8% of vegetables, 7% of forages, 5% of fruits, 2% of roots and tubers, and ca. 2% of oil crops. Spices and medicinal, aromatic and ornamental species are rarely found in long-term public collections.

As far as major crops are concerned, the size of collections varies rather largely (Table 2; Fig. 3): wheat is first with 788,000 accessions (13% of total *ex situ*), followed by barley with 487,000 (8%), rice with 420,000 (7%), maize with 277,000 (5%). Cassava, on the other hand, is less represented (0.5%). For wheat, rice, potato cassava, banana/plantain, sorghum, yam, sweet potato, chickpea, lentil and bean, the largest *ex situ* collections are held by the IARCs; for other crops the largest collections are in national institutions. Minor crops are poorly represented in *ex situ* collections; for example, there are only about 12,000 accessions of all species of yams (0.21%) and less of coconut (0.16) and many others. However, recently some genebanks have begun to accept regional responsibility for long-term storage of some minor crops: rice bean, moth bean and amaranth at National Bureau for Plant Genetic Resources (NBPGR), in India, winged beans at the Institute of Plant Breeding College of Agriculture (IPB-UPLB), Laguna, in the Philippines and at the Thailand Institute of Scientific and Technical Research (TISTR), Bangkok, in Thailand, faba beans at the International Centre for Agricultural Research in Dry Areas (ICARDA), Aleppo, in Syria, and adzuki beans at the National Institute of Agrobiological Research (NIAR), Tsukuba, in Japan. It is interesting to note that, for many export crops and commodities, large percentages of the global collections are concentrated in few countries: oil palm accessions in Zaire (83%), most rubber accessions (76%) in Malaysia and of coconut (22%) in Sierra Leone.

According to the type of genetic variation within *ex situ* collections, about 32% are advanced cultivars, 24% are landraces or old cultivars, 5% advanced landraces, 8% are wild or crop relatives and the remaining being 31% (Fig. 4).

Some countries are consolidating national collections (*in situ* and *ex situ)* of indigenous genetic resources, which are of potential importance for the country itself. Quantitative estimates for 24 countries (Table 3) show that only few countries (for example, Ethiopia, Cyprus, China, etc.) store high percentages of indigenous plants, although it is impossible to say how representative current *ex situ* collections are of total diversity. However, landraces of cereals are probably more "covered" than those of pulses, root crops, fruit and vegetables (excluding potato and tomato).

Table 1. Ex situ *collected and stored accessions, by crops, maintained in national and CGIAR gene banks.*[1]

Crop	National collections (a)	CGIAR centres (b)	Total[2] (c)	% a/g	% b/g	% c/g
Cereals	1.971.000	362.000	2.333.000	37	60	39
Food legumes	758.000	132.000	890.000	14	22	15
Vegetables	481.000	–	481.000	9	,	8
Forages	350.000	58.000	408.000	6	10	7
Fruit	279.000	–	279.000	5	,	5
Roots and tubers	77.000	24.000	101.000	1	4	2
Oil crops	95.000		95.000	1,8		1,7
Banana		2.500	2.500		0,4	<0.1
Sugar crops	45.500		45.500	0,8		0,7
Beverages	43.000		43.000	0,8		0,5
Condiments	17.700		17.700	0,3		0,3
Cacao crops	9.400		9.400	0,2		0,2
Rubber	31.000		31.000	0,6		0,5
Fibre crops	76.300		76.300	1,4		1,3
Narcotics and drugs	28.000		28.000	0,5		0,5
Shelter crops	10.000		10.000	0,2		0,2
Ornamentals	23.200		23.200	0,4		0,4
Medicinal plants	2.300		2.300	<0.1		<0.1
Dyes	1.000		1.000	<0.1		<0.1
Perfume crops	600		600	<0.1		<0.1
Building materials	400		400	<0.1		<0.1
Others	1.100.600	21.500	1.122.100	20	4	19
Total (g)	5.400.000	600.000	6.000.000	100	100	100

[1] *Ex situ* collections consist of: seed genebanks, field genebanks and *in vitro* genebanks.
[2] Seed genebanks (5,435,000 accessions); field genebanks (527,000 accessions); *in vitro* genebanks (38,000 accessions). Considering duplicates within and between collections, the total number of accessions is estimated to be from 1 to 2 million.
Sources: Plucknet *et al.*, 1987; Scarascia Mugnozza, 1994; FAO Views database, 1996.

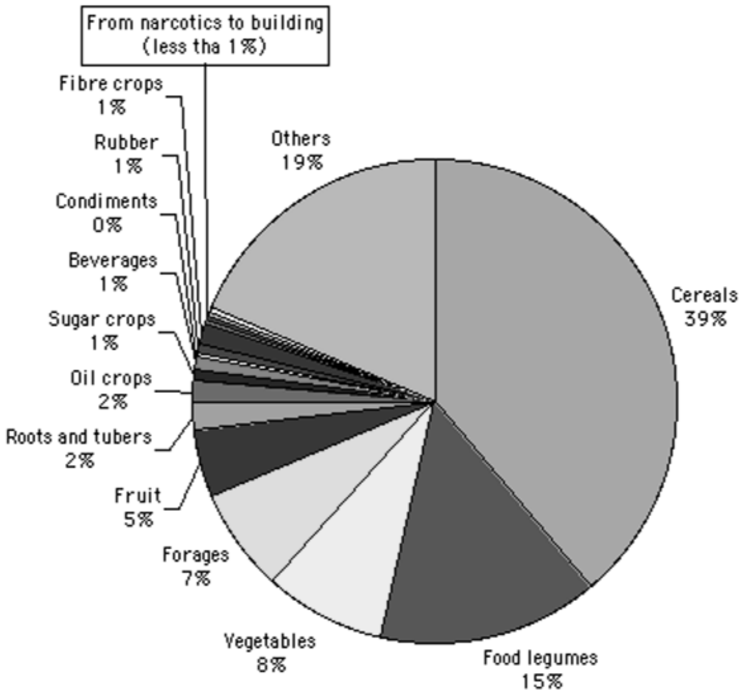

Fig. 2. Worldwide *ex situ* germplasm collections maintained by national and regional genebanks, and CGIARs centres (total: 6,000,000 accessions, see table 1).

Coverage of wild relatives is limited, and that of forest ornamentals, aromatic, medicinal and forage species is minimal. Worldwide, there are gaps in the collections of minor crops and under utilized species, especially for landraces and wild relatives from their centres of diversity and cultivations. Targeted collecting of selected species and assessments of the genetic diversity of landraces are, therefore, priorities (Padulosi, 1996).

2.3.2. *Storage facilities*

Methods for germplasm conservation are determined by a number of factors: purpose (programmes to conserve genetic diversity for prosperity or for present and short term use), storage behaviour (type of seeds: orthodox, recalcitrant or

Table 2. Ex situ *germplasm collections of selected crops maintained in the six largest countries, national and regional genebanks, and CGIAR centres.*

Crop	World collections x 1.000	Major holders and percentage per crop world collection	% above all collections (6.000.000)
Wheat	788	Cimmyt (13), USA (7), Russia (6), India (6), Germany (6), Italy (5)	13,01
Barley	487	Canada (14), USA (11), UK (6), ICARDA (5), Brazil (5), Russian F. (5)	8,01
Rice	420	IRRI (19), China (13), India (12), USA (8), Japan (5), WARDA (4)	7,01
Maize	277	Mexico (12), India (10), USA (10), Russian F. (7), Cimmyt (5), Colombia (4)	4,35
Phaseolus	268	CIAT (15), USA (13), Mexico (11), Brazil (10), Germany (3), Russian F. (3)	4,25
Oat	223	Canada (30), USA (20), Russian F. (7), Kenia (7), Israel (4), Australia (3)	3,59
Soybean	176	China (15), USA (14), AVRDC (10), Brazil (5), Ukraine (4), Russian F. (3)	2,85
Sorghum	168	ICRISAT (21), USA (20), Russian F. (6), Brazil (6), Ethiopia (4), Australia (4)	2,79
Brassica	106	India (16), UK (10), Germany (9), USA (8), China (6), Korea (3)	1,75
Eggplant	91	Several (85), Russian F. (11), China (1), Philippines (1), Tari (1)	1,52
Millet	90	ICRISAT (25), China (6), France (6), USA (5), India (4), Canada (3)	1,51
Cowpea	85	IITA (19), Philippines (12), USA (11), AVRDC (7), India (6), Indonesia (5)	1,41
Groundnut	81	USA (27), India (20), ICRISAT (18), China (8), Argentina (6), Zambia (2)	1,23
Tomato	78	USA (30), AVRDC (9), Philippines (6), Russian F. (4), Germany (4), Colombia (3)	1,19
Pea	75	UK (13), USA (6), Germany (6), Poland (6), Italy (5), Australia (4)	1,13
Chickpea	70	ICRISAT (26), ICARDA (15), Pakistan (9), USA (9), Iran (8), Russian F. (4)	1,14
Capsicum	53	Mexico (17), AVRDC (10), Bulgaria (8), USA (6), Russian F. (3), Philippines (3)	0,86
Cotton	49	India (34), France (13), Russian F. (12), USA (6), Pakistan (5), China (3)	0,81
Faba bean	32	ICARDA (33), Germany (18), Italy (13), Spain (6), Russian F. (6), France (6)	0,53
Sweet potato	32	CIP (21), Japan (12), USA (8), Peru (6), Philippines (5), Several (4)	0,53
Lupin	31	Spain (14), Australia (12), France (11), Peru (6), Germany (6), UK (4)	0,52
Potato	30	CIP (20), Colombia (13), Germany (13), USA (8), Argentina (4), Czech R. (4)	0,51
Cassava	28	CIAT (21), Brazil (12), IITA (8), Uganda (6), India (5), Malawi (4)	0,47
Rubber	27	Malaysia (76), Brazil (6), Cote d'Ivoire (5), Liberia (4), Viet Nam (4), Indonesia (2)	0,45
Rye	27	USA (14), Germany (12), Canada (11), Russia (11), Poland (10), Severals (41)	0,45
Lentil	27	ICARDA (30), USA (10), Russian F. (8), Iran (7), Pakistan (4), India (3)	0,45
Pigeonpea	25	ICRISAT (52), USA (17), India (6), Kenia (4), Others (21)	0,42
Garlic/onion	25	Germany (18), UK (10), India (8), Russian F. (5), Hungary (6), France (4)	0,42
Sugarbeet	24	Germany (25), France (12), Netherlands (9), Yugoslavia (9), Russian F. (7), Japan (5)	0,41
Sugar cane	23	Brazil (20), India (18), WICSCBS (Barbados) (11), USA (9), Domenican R. (9), Cuba (6)	0,38
Oil-palm	21	Zaire (83), Malaysia (7), Brazial (3), Ecuador (1), Colombia (1), Indonesia (1)	0,35
Coffee	21	Cote d'Ivoire (35), France (20), Cameroon (7), Costa Rica (7), Ethiopia (6), Colombia (5)	0,35
Cucurbita	17	Costa Rica (12), USA (14), Russian F. (12), Hungary (7), Brazil (6), Severals (50)	0,27
Yam	12	IITA (25), Cote d'Ivoire (20), India (8), Philippines (5), Sri Lanka (4), Solomon Is. (4)	0,21
Banana/ plantain	11	INIBAP (10), France (9), Honduras (9), Philippines (6), Papua N.G. (5), Cameroon (5)	1,68
Cocoa beans	10	Brazil (24), Trinidad (22), Venezuela (17), France (7), Costa Rica (6), Colombia (5)	1,68
Taro	6	Malaysia (22), Papua N.G. (13), India (11), USA (8), Indonesia (7), Philippines (6)	1,01
Coconut	1	Sierra Leone (22), Venezuela (20), France (17), India (13), Colombia (11) Philippines (9)	0,16
Forages	350	New Zeland (19), CGIAR (18), Australia (10), Poland (7), Syria (6), Japan (4)	6,68
Fruit	279	Sweden (14), China (11), France (5), Canada (5), Ukraine (3), Italy (2)	4,58
Others (*)	1356	Several countries, national and regional genebanks, and CGIAR centres	19,08
TOTAL	6000		100,00

(*) Include some: oil crops, beverages, condiments, cacao, fibres, shelter, dyes, medicinals, perfume, etc. (see table 1).
Source: FAO Views database, 1996; G.T. Scarascia Mugnozza, 1994.

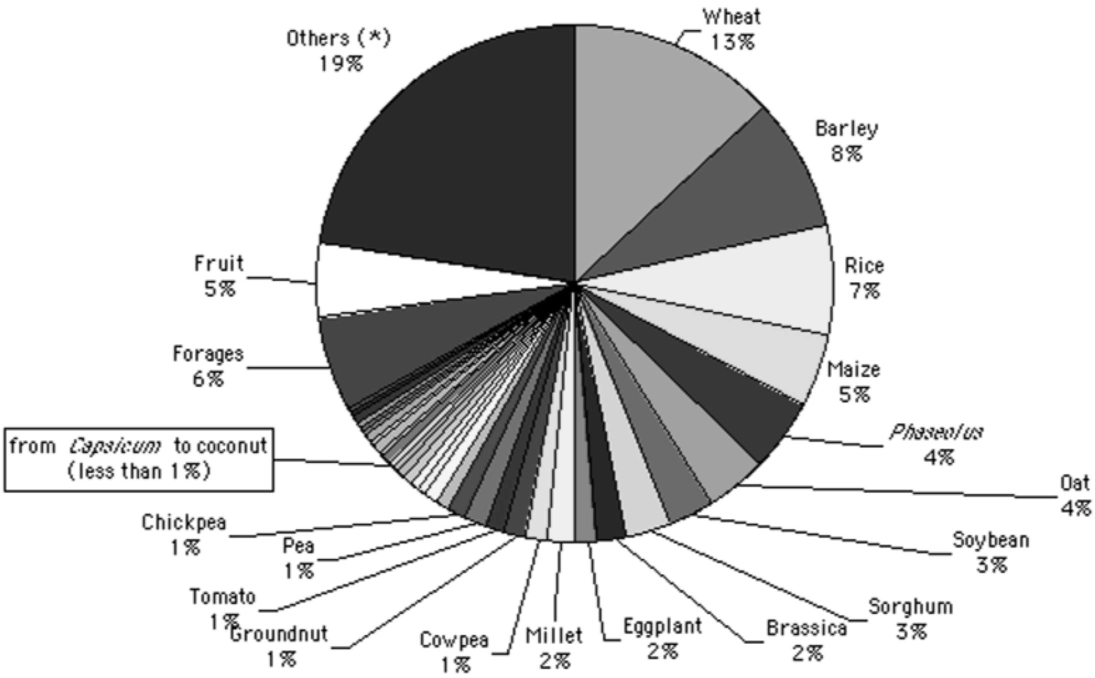

Fig. 3. *Ex situ* germplasm collections of selected crops maintained worldwide (see table 2).

intermediate), resources (financial, human and institutional capacities and technologies) (Table 4).

By the end of the 1970s, there were about 54 seed stores. Today, besides the genebanks of the IARCs, there are over 1,300 national and regional genebanks and seed storages on field collections, 397 of which are maintained under long- or medium-term storage conditions. In fact, many countries have more than one *ex situ* facility or collection (70 in India), although in many cases these are active or research collections. Many of the collections are breeders' or working collections, and likely to be short-term. Of the 1,308 genebanks registered in the VIEWS database, 496 (38%) are located in Europe, 328 (25%) in the Americas, and 293 (22%) in Asia (Table 5). The 15 largest national base collections together hold about 1.7 million accessions or 34% of the national seed collections (Table 6).

A total of 75 countries have facilities for medium- and long-term storage, but in many cases the major constraints to reliable storage are: equipment, suitable drying facilities and electricity supplies. Based on the Country Reports, secure,

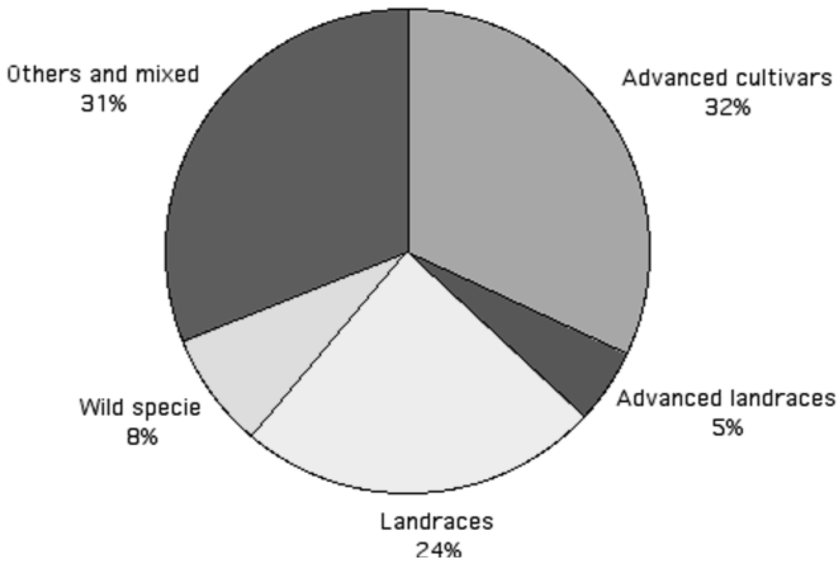

Fig. 4. Kind of accessions in the world *ex situ* collections (total number: 6,000,000 accessions).

long-term seed storage facilities are found in 35 countries: 15 in Europe, 7 in the Americas, 5 in Asia, 4 in Africa and 4 in Near East regions. A further 56 countries have facilities for short- to medium-term storage only.

According to FAO Views database, only about 56% of the accessions are stored in medium- or long-term conditions. Nearly 8% are stored in short-term, 1% in short/medium and 10% in field collections, *in vitro* or under cryopreservation. No information is available for 25% of the accessions (Fig. 5).

2.3.3. *Field genebanks and* in vitro *facilities*

Plant species that are vegetatively propagated, or have long life cycles or species which produce short-lived (recalcitrant) seed, are usually maintained in field genebanks, existing in at least 103 countries. These include crops like: fruit trees of temperate zones, potato, cassava, banana-plantain, yam and tropical fruits, rubber, coffee, cocoa and coconut. Nevertheless, improvement and development of appropriate conservation technologies for vegetatively propagated plants (FAO, CGIAR-SGRP, IPGRI and CIAT, 1996), as well as for species with non-orthodox seeds, are needed.

Table 3. *Indigenous accessions in national genebanks.*

Country	Percentage
Europe	
Bulgaria	12
Czech Republic	16
Republic of Moldova	40
Romania	71
Slovakia	8
Belgium	75
Africa	
Cameroon (roots and tubers)	75
Cameroon (fruits)	25
Ethiopia	100
Mauritius	100
Angola	100
Malawi	100
Namibia	100
Senegal	10
Near East	
Islamic Republic of Iran	95
Cyprus	100
Iraq	22
America	
Brazil	24
Colombia	55
Ecuador	52
United States	19
Asia	
China	85
Democratic People's Republic of Korea	20
Republic of Korea	18
Sri Lanka	67

Source: 24 Country Report, FAO, 1996.

Table 4. *Technologies for* ex situ *conservation according to the type of plant genetic resources.*

Storage technology	Type of genetic material	Adequate storage
Dessicated seeds at low temperature (-18°C) and 3-7% moisture content	Orthodox seeds	Long-term conservation (base collection); provision of accessions for use (active collection)
Dessicated seeds at cool temperature	Orthodox seeds	Provision of accessions for use (active and working collections); medium-term conservation (base collections)
Ultra-dry seeds at room temperature	Orthodox seeds	Medium- to long-term conservation
Storage of dried seeds at room temperature	Some long-lived orthodox seeded species	Provision of accessions for use (active and working collection)
Cultivation of entire plants in field genebank	Vegetative species and some non-orthodox seeded species	Short or medium-term conservation (base collections); provision of accessions for use (active collections)
Slow growth under serial *in vitro* propagation	Vegetative species and some non-orthodox seeded species	Medium-term conservation; provision of accessions for use active collections)
Cryopreservation at 196°C in liquid nitrogen or- 154°C to 196°C in N_2 vapour	Seeds, pollen, tissue, cells, embryos of species capable of *in vitro* regeneration after drying and freezing	Long-term conservation
Freeze-dried seeds or tissue	Seed or plant tissue	Medium- to long-term conservation, deopending on the species

Source: FAO Views database, 1996.

Table 5. *Number of Genebanks and accessions in ex situ collection, by region.*

Region	Accessions		Genebanks	
	Number	%	Number	%
Africa	353,523	6	124	10
Latin America, the Caribbean	642,405	12	227	17
North America	762,061	14	101	8
Asia	1,533,797	28	293	22
Europe	1,934,574	35	496	38
Near East	327,963	6	67	5
Total	**5,554,505**	**100**	**1,308**	**100**
CGIAR Total	**593,191**		**12**	

Source: FAO Views database, 1996.

Table 6.

	No specific germplasm collections	Wild crop relatives, ornamentals threatened indigenous species	Forestry, medicinal and species of ethnobotanical interest	Agricultural crops and wild food plants	Total
Europe Union	196	103	45	27	371
Former Soviet Union	104	52	20	22	198
Europe remainder	81	21	13	8	123
Africa	50	35	8	0	80
India	38	14	12	13	77
China and Japan	50	30	16	8	104
Asia	40	20	9	12	81
Australia and the Pacific	51	34	12	9	106
South America	50	15	9	0	74
Central America and the Caribbean	35	8	7	0	50
North America	107	78	18	20	223
Total (number of botanic gardens)	**802**	**410**	**168**	**119**	**1500**

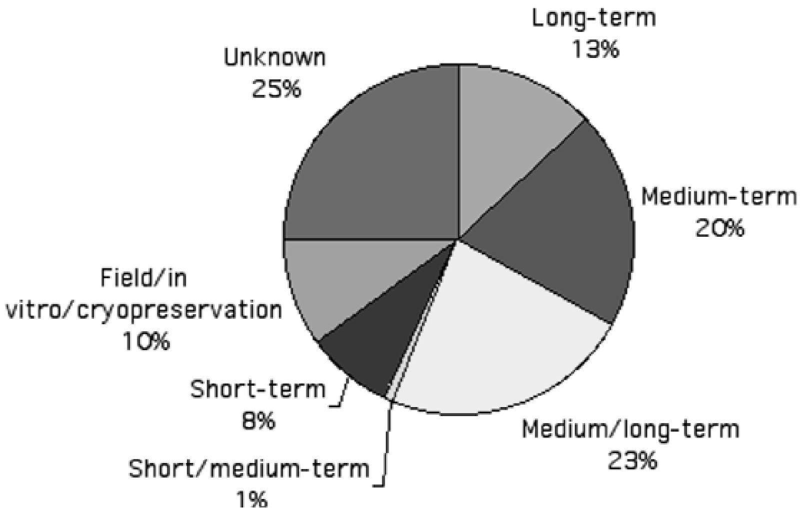

Fig. 5. Maintainance of the world *ex situ* collections by storage facilities (Total no. of genebanks: 1308; total no. of *ex situ* accessions: 6,000,000).

Approximately 527,000 accessions are stored worldwide in field genebanks: 284,000 in Europe, 10,000 in Near East, 84,000 in Asia and the Pacific, 16,000 in Africa, 117,000 in the Americas (Fig. 6).

More than sixty countries have *in vitro* conservation facilities. *In vitro* storage is an alternative or complementary method, for conserving vegetatively propagated plants, or with long life cycles and with recalcitrant seeds (Table 7), which has been developed up to now for a small number of species, being a technology requiring expensive equipment and skilled staff. The total number of *in vitro* accessions is about 38,000 (cassava, potato, sweet potato, Andean root and tuber crops, yam, banana/plantain, cocoyam, grasses, etc.) and are stored in about 63 *in vitro* genebanks, mostly at IARCs. There are, however good examples also at National Agricultural Research Systems, as for instance the papaya collection at Malaysian Agricultural Research and Development Institute, in Malaysia.

2.3.4. *Botanical Gardens*

Worldwide, the 1500 Botanic Gardens (11% private) maintain living collections of plants (Fig. 7). About 10% of them have also seed banks, and 2% *in vitro* collections. Usually, vegetatively propagated species, forest trees, medicinal and ornamental species, as well as plant genetic resources for food and agriculture of local significance are well represented. In this way they can fill an important gap in *ex situ* conservation programmes. Because their mandate extends to all plant

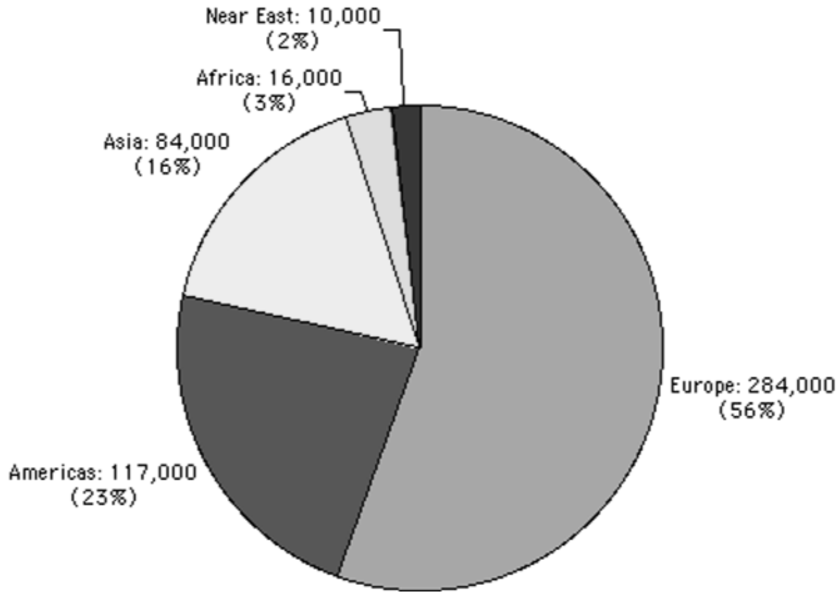

Fig. 6. Distribution of field genebanks in the world (total number: ca. 527,000).

species, botanical gardens are characterized by few accessions per taxon, and — consequently — by a high interspecific but low intraspecific genetic diversity.

Most of the botanic gardens (915) are situated in Europe, the Former Soviet Union, and the United States, where about 75% of the total germplasm of botanic gardens is conserved. Worldwide, 698 (47%) have germplasm collections, 80% of which are preserved as living collections, outdoors or in greenhouses. In particular the situation is as follows: 410 botanic gardens conserve ornamental species or wild native endangered species, many of them related to major crops; about 60% of these collections are in Europe, USA, Japan, South Africa and Mexico; 169 conserve also medicinal and forest species; particularly in China, Japan, India and Brazil; 119 conserve germplasm of cultivated species, including landraces, semi-cultivated species and other wild species locally utilized. These collections can be found in Asia (India and China), Mesoamerica (Mexico) and Canada.

Only 60% have manual (75%) or computerized databases (25%) and the origin is known for only about half of the accessions.

The *Index seminum* Commission has been the main mechanism for germplasm exchange since 300 years, and about 2 millions of accessions are offered every year, but the feedback on how the germplasm is used is very poor.

Table 7. *Examples of species with recalcitrant seeds.*

Botanical name of plant	Plant name
Araucaria spp.	Araucaria
Castanea spp.	Chestnut
Chrysophyllum cainito	Caimito
Cinnamonum zeylanicum	Cinnamon
Durio spp.	Durian
Erytroxylum coca	Coca
Garcinia spp.	Mangosteen
Hevea brasilianensis	Rubber tree
Diospyros spp.	Ebony
Cocos nucifera	Coconut
Diospyros spp.	Ebony
Mangifera spp.	Mango
Manilkara achras	Zapote
Myristica fragans	Nutmeg
Nephelium lappaceum	Rambulan
Spondias spp.	Jocote
Swietenia mahagoni	Mahogony
Syzygium aromaticum	Clove
Theobroma cacao	Cocoa
Persea spp.	Avogado
Quercus spp.	Oak
Thea sinensis	Tea

Source: FAO Views database, 1996; IPGRI various Newsletters.

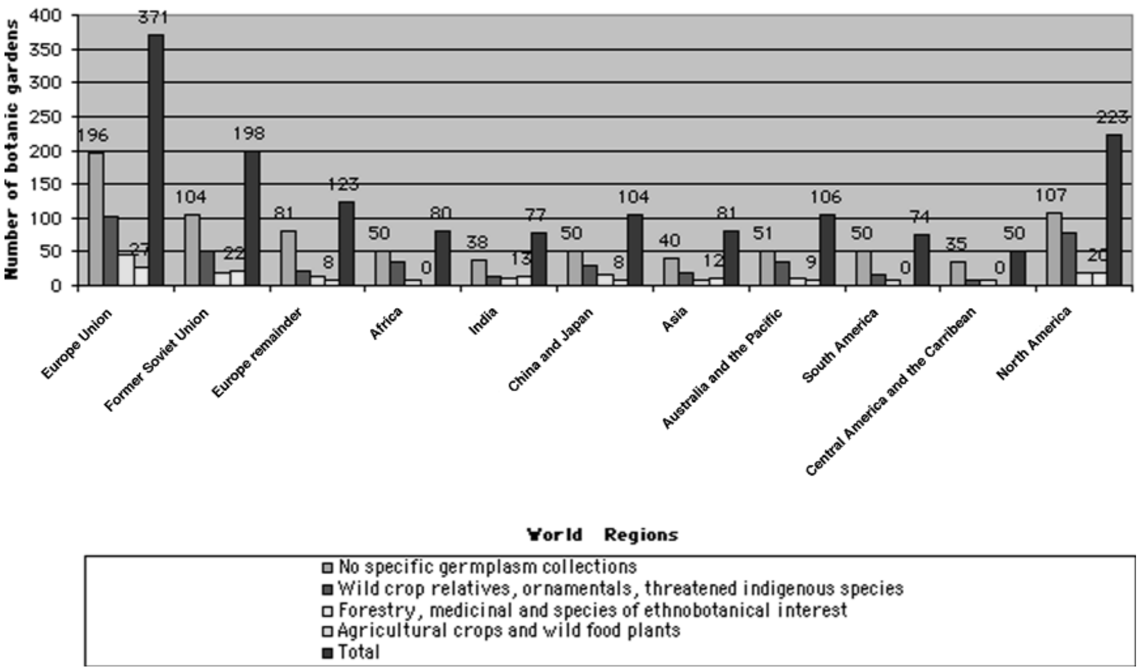

Fig. 7. Botanic gardens preserving plant biodiversity, by world regions and groups of species (1,500 botanic gardens worldwide preserve thousand of species with very few accessions (per taxon).

2.3.5. *Evaluation of the collections*

In general, genebanks were installed in the 1970s and 1980s in response to genetic erosion. The urgency of the moment led to the rescue and amassing of collecting and conserving a huge amount of plant genetic resources, not followed by an extended evaluation and utilization. Thus, very little information can be found on the Country Reports. Only 55 countries provided this kind of information, and only low percentages of the collections have been subjected to some form of evaluation.

The situation for IARCs is, generally, better reported and mainly related to the resistance to pests and diseases. Most of the centres perform multi-site evaluation of accessions for desirable characteristics in different agro-ecological regions. So far, there are a few examples of germplasm being systematically evaluated using a network approach, at national and international level. For instance the "International Network for Genetic Evaluation of Rice (INGER)", coordinated by IRRI and operating for 20 years, has greatly contributed to the increase of rice germplasm. Similarly, the International Network for the Improvement of Bananas and Plantains (INIBAP), working mainly through NARS, has developed the "International Musa Testing Programme" for the evaluation of banana and plantain collections. In the USA, several public sectors and private institutions are collaborating with the "United State Germplasm Enhancement Maize project (GEM)", which is broadening the genetic base of maize hybrids. It is evident that an international cooperation, deeper documentation and information, and a more systematic evaluation in relevant environments are needed.

2.3.6. *Distribution of germplasm from genebanks*

In general, germplasm from genebanks and botanical gardens is freely available to *bona fides* users upon request; however, increasingly access restrictions are being introduced: for instance, quarantine regulations.

A fundamental achievement is represented by the legal status of the CGIAR genebanks. The legal status of CGIAR and other *ex situ* collections was left unresolved until after the implementation of the UNCED Convention on Biological Diversity (CBD), in 1993. The CBD offers the signing states international rights over their national resources (art. 3). The CBD does not cover *ex situ* collections, which were acquired prior to the implementation, e.g. the majority of the accessions in the CGIAR collections. The importance of the issues of *ex situ* collections and Farmers' Rights was further emphasized during the Nairobi Conference for the Adoption of the Agreed Text of the CBD in 1993. Soon after, the FAO adopted Resolution 7/93 called for intergovernmental negotiations on: "the issue of access on mutually agreed terms to plant genetic resources, including *ex situ* collections, not addressed by the Convention, and the issue of the realization of Farmers' Rights'" (FAO, 1995). On 26 October 1994, the 12 CGIAR centres holding plant genetic resources placed them under the auspices of the FAO International Network of *ex situ* collections, part of the FAO Global System (FAO, 1995).

At present, information on the utilization of conserved genetic resources for breeding and other purposes is rather scanty. One of the few available indicators of utilization from national genebanks is the number of accessions distributed each year and expressed as a percentage of the total number stored in the genebank. Only very few genebanks distribute more than 10% of their accessions annually. For instance, the USA distributes yearly over 100,000 samples concerning more than 3,000 species. An explanation of the low use of genebanks collections by breeding programmes is due to the fact that most plant breeding programmes have their own working germplasm collections. It is also evident that most genebanks distribute material only from a limited number of the total species conserved. In general, a large proportion of accessions are distributed to National Agricultural Research Service (NARS) mainly in developing countries; a much lower amount goes to the private sector. The distribution of accessions from the CGIAR centres varies widely (Table 8). Most centres distribute at least 10% of their total accessions every year; a rate higher than that for most national genebanks.

Table 8. *Percentage of germplasm samples distributed annually by CGIAR centres, by sector (1992-1994).*

Centres	Other international agricultural research centers	Developing country national agricultural research system	Developed country national agricultural research system	Private sector	Total number of samples distributed outside the centres
	%	%	%	%	No.
CIAT					
Phaseolus	0	54	46	0	1,979
Manihot	0	59	40	1	422
Forage legumes	16	51	27	6	1,655
Total	**7**	**53**	**37**	**3**	**4,056**
CYMMIT					
Maize	0	20	72	8	2,234
Wheat	0	69	28	3	2,372
Total	**0**	**45**	**49**	**6**	**4,606**
WARDA					
Total	**25**	**75**	**0**	**0**	**1,872**
ICARDA					
Total	**5**	**63**	**32**	**0**	**13,013**
CIP					
Potato		93	7		3,929
Sweet potato		95	5		1,023
Total		**93**	**7**		**4,952**
IITA					
Total	**13**	**66**	**21**	**0**	**3,895**
ICRISAT					
Total	**0**	**91**	**2**	**7**	**19,570**
IRRI					
Total	**7**	**52**	**39**	**2**	**7,207**
ILRI					
Total	**9**	**64**	**7**	**20**	**1,071**
INIGAP					
Total	**3**	**64**	**33**	**0**	**371**
TOTAL	**4**	**72**	**21**	**3**	**60,613**

Source: SGRP Review of the CGIAR Genebank Operations, 1996.

2.3.7. *Remarks and improvement of the system*

It has become increasingly clear that the *ex situ* collections and the system of genebanks need to be strengthened. Concerns are based on: gaps in the collections of minor crops and under utilized species, especially landraces and wild relatives from their centres of diversity and cultivation; a large and increasing number of accessions needs regeneration; several important species with non-orthodox seeds cannot be stored in seed genebanks; many countries lack resources to maintain germplasm that they or the international community have already paid to collect; few genebanks operate in conformity with the highest international standards, while much of the germplasm in the remaining ones is threatened in its genetic integrity; duplication of accessions is far from complete, while there is a significant over duplication of samples; documentation is variable and incomplete; access to information is limited; coordination between genebanks, breeders and other users is insufficient.

On such premises, improvement of the genebank system for *ex situ* collections could be attained following a number of measures, such as: identification of priorities to fill gaps in collections; increase regeneration efforts; complete safety duplication of collections; increase primary characterization, evaluation and documentation to facilitate collaboration with breeders and to promote the sustainable use of plant genetic resources; develop low-cost conservation technologies, particularly for non-orthodox seeds and vegetatively propagated plants, including *in vitro* methods and cryopreservation; improve the linkages between *ex situ* and *in situ* conservation, promoting also a common database.

Finally, the need to maximize synergy through collaboration at national, regional and international levels is necessary, including the rational organization of base, active and working collections. This might include mechanisms to allow countries to place their material in secure storage facilities outside their borders, without compromising their sovereign rights. Financing mechanisms may be required to facilitate such rationalization of activities.

3. Genetic resources: maintenance, use and regulation

3.1. *EX-SITU* VERSUS *IN SITU* AND ON-FARM CONSERVATION OF AGROBIODIVERSITY

What are the real problems and the prospective, matured in the last decade, what are the implications, the possible approaches, in relation to collecting maintaining, evaluation of agrobiodiversity?

Of course, collecting and conserving *ex situ* biosamples in genebanks is of undoubted technical and economic advantage to both holders and users of germplasm, and it has been instrumental in the success of many national and international plant improvement programmes, leading to significant increases in productivity, as did the green revolution.

However, while genebanks will continue to play their specific role, biological evolution, that is, the continuous creation of biodiversity, cannot take place in stored material. It can only occur in nature, through the dynamics of continuous contact and interaction among life forms in ecosystems or, for crop plants and domestic animals, in agro-ecosystems.

During the recent years, national and international programs, following the large public calls towards nature conservation and "to protect nature from man", have increased the *in situ* biodiversity conservation through increasing number of protected areas and reserves, supported also by UNESCO-MAB program, the Global Environment Facility of UNDP and UNEP projects and according to the multifaceted strategy developed at the UNESCO Seville Conference (1995).

The need to allow such processes to continue has prompted an increasing engagement in *in situ* programmes of biodiversity conservation. The Convention on Biodiversity (CBD) itself, in Article 8, promotes *in situ* conservation when it explicitly calls on signatory parties to "… establish a system of protected areas, or areas where special measures need to be taken, to conserve the biological diversity …", with the aim of ensuring the conservation of ecosystems and agrobiodiversity, and of guaranteeing the sustainable utilization of the latter.

Moreover, outside gene parks and protected areas, *in situ* conservation is often carried out at the farm level, the "*on-farm conservation*", where landraces and locally improved material are grown, utilized and conserved as components of traditional farming systems, and where they evolve in response also to their dynamics. Agricultural populations have, over millennia, conserved plant and animal genetic resources and practised selection for yield, quality, resistance to biotic and abiotic stresses and for medicinal and other economic prospectives. Therefore, it is right and fair that *in situ* conservation, again according to the CBD, should aim to "… respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity … and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices".

However, as most *in situ* management practices have been directed toward habitat preservation and have focused on ecological rather than genetic considerations, technical expertise on conservation strategies and techniques focused on *in situ* conservation of useful species should be intensified.

It may be concluded that the *in situ* or, under specific conditions, *on-farm* conservation and growing of crop, domestic animal and agroforestry species may play a significant role not only in the effective maintenance of agrobiodiversity, but also as a component of sustainable development programmes, as also recognized by Agenda 21. Measures, such as the establishment of a multilaterally agreed funding mechanism, should therefore be taken to promote, encourage and implement *in situ* and *on-farm* conservation.

3.2. Use of genetic resources

Use and exploitation of genetic resources postulate knowledge and evaluation of the characters expressed by the genome of the samples and the identification of desirable traits.

Research on genetics, molecular biology, plant genomics, agricultural biotechnology, microbiology, cytology, biochemistry, chemistry, agronomy, physiology, pathology, entomology, human nutrition, pharmacology, environmental sciences, biophysics, bioinformatics, etc., has allowed the development of more and more refined methodologies which make now geneticists and biotechnologists able to pursue their programs. In particular, the new scientific and technical tools should be progressively applied to scan the genome of specific valuable accessions.

A really essential project fundamental for the preservation, knowledge, evaluation, utilization of all biological diversity, and consequently basic for the use and valorisation of agrobiodiversity, was designed, during 1999, in Paris meetings of the "OECD Megascience Forum". It was decided to establish — in the frame of the UNEP Global Environmental Facility — a "Global Biodiversity Information Facility (GBIF)", corresponding to the aims of the Rio Convention. A Steering Committee among countries supporting this decision should be operative since this year 2000. In fact, the goals of GBIF include the development of a mechanism to encourage, promote, and facilitate information and the exchange of information and data in the field of biodiversity, as well as to provide training in developing countries in the same field. GBIF is intended to work in close cooperation with established programmes and organizations maintaining and using biological information resources, and specifically with the clearing-house mechanism of the CBD, as well as with the relevant national and international organizations as: UNEP, FAO, UNESCO, CGIAR and others.

Like biodiversity itself, information on conservation, preservation and evaluation of biodiversity and genetic resources are already distributed worldwide, and practically contained in electronic data-bases (distribution of organisms around the globe, information on physiological functions of organisms also in relation with ecosystems, detailed genomic maps, etc.) often compiled during unrelated and independent projects.

GBIF should strengthen preservation and utilization of knowledge and expertise on biodiversity by providing access and links to existing or new databases, synchronizing and planning for interoperability of them, developing novel interface designs and protocols for indexing and validation of documentation, etc. Of primary importance will be the role of GBIF in the exchange of data, information, and resources. Therefore, a clear agreement should be reached in which intellectual property rights, as well as breeders' and farmers' rights will be equitably protected and guaranteed.

In recent years the epochal event represented by the development of biological sciences, especially molecular biology, and animal and plant genomics, and the results of the biotechnological research and applications made increasingly evident that biotechnology can add value to genetic resources and biodiversity at large. The successful use of genetic engineering methods has raised the economic value and increased the potential of much biological diversity as a resource in breeding and research. Consequently, it has widened enormously the scope and boundaries of initiatives to protect and conserve biodiversity.

Acknowledging intimate connection of biotechnologies with biodiversity, underlined also by the FAO Commission on genetic resources, access (Article 16 of the CBD) to the know-how research institutions should be facilitated, for instance in joint ventures that help transfer technology from North to South and training of personnel could also be envisaged.

There may be unique opportunities for real international cooperation among developing and industrialized countries in building local capacities in developing countries, for the application of agrobiotechnologies to agrobiodiversity. Equitable and effective cooperation through technology transfer constitutes one of the major mechanisms by which resources of biodiversity can be conserved, managed and used sustainable for human welfare. Equity demands that developing countries receive benefits and compensation for the use of these resources, by improving their capacity to maintain their agrobiodiversity *in situ* or *ex situ,* to identify and evaluate useful genetic traits for plant and animal improvement and to apply the relevant biotechnologies for the optimal use of genetic resources, for the benefit of their populations.

In any case, it is important to underline "that the realisation of benefits from such technologies depends on the continued conservation and availability of the biological resources. Investments in technology development should be made hand-in-hand with investment to protect the resource base" (FAO, 1996).

3.3. Legal issues and rights

Since the feedstock for the biotechnology industry is biological diversity, it is necessary to formulate and adopt some basic ground rules which could regulate questions concerning above all: conservation, use, ownership, access, benefit-sharing, indigenous rights, farmers' rights, intellectual property rights and patenting system. These issues are technically and legally complex, but they can be efficiently faced by the international community if our action proceed along the path traced by the principles of the Convention of Biological Diversity: conservation of biodiversity, sustainable use of its components, access to and transfer of genetic resources accumulated in *ex situ* genebanks or *in situ* maintained, and equitable sharing of the benefits of the use of genetic resources. This was confirmed by the

FAO during the last decade,[2] in the Leipzig Declaration (June 1996) and in the Global Plan for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Further confirmation was given by the "Madras Declaration" (July 1996), a ten-point action plan for achieving at national, regional and global levels, the concept of food and nutrition security, adopted by the Science Academies Summit, cosponsored by the Academies of Sciences of India, Italy and of the Third World, and by an appeal of the Academies of Sciences of India and Italy supported by about 1000 scientists and experts belonging to more than 90 countries and international Agencies (Scarascia Mugnozza and Swaminathan, 1996). The FAO — World Food Summit (Rome, November 1996) declared, among the objectives of its third commitment, a solemn support to the Leipzig plan of action through "inter alia appropriate *in situ* and *ex situ* approaches, systematic survey and inventorying to broaden the genetic basis of crops, and fair and equitable sharing of benefits arising from the use of such resources". The same questions were debated at the World Conference on Science (UNESCO, Budapest, 1999), which had to recognize that the expansion of intellectual property rights — controlled science is inevitable. Among the easily imaginable consequences: increasing of the secrecy in scientific work and inattention towards the scientific problems related to the health and livelihoods of the poor.

Therefore, as Swaminathan said: "It is necessary for every nation and for the international scientific community to develop some basic ground rules for ensuring that science serves public good in an era of expanding IPR". In the light of the above, it is extremely urgent that a timely agreement be reached among holders of germplasm throughout the world in order to regulate the status and access to genetic resources and that an efficient mechanism be identified to assure equitable sharing of the benefits derived from their use.

Very recently, the FAO Commission on Plant Genetic Resources for Food and Agriculture, during its last session (April, 2000, see point 2.2.8.), made further progress in searching for the development and establishment of an international *sui generis* system, which provides recognition, and protection of farmers and traditional communities' rights for an equitable share of the benefits.

Apart from the fundamental need of strengthening international cooperation to achieve suitable participatory systems of sharing benefits in a wide range of approaches and actions, we think that key-issues, within the ongoing international debate on plant genetic resources, are namely: a) the problems related to the realization of Farmers' Rights confronted to the patent system, being them complementary and not opposed against to Breeders' Rights and b) the status of the collections *ex situ* prior to the approval of Convention on Biological Biodiversity in

[2] In 1995, the introductory McDougall memorial lecture to the general FAO Conference was dedicated to the potentialities and perspectives of the biological diversity for food and agriculture (G.T. Scarascia Mugnozza, 1995).

1993, remained out of the reach of the provisions of the Convention itself. Thus, the continuing uncertainty on the legal status of their ownership and related aspects of access and maintenance represent a threat to conservation of plant genetic resources. FAO-CGIAR Agreement of 1994 should be regarded as a major contribution to an open system of germplasm conservation and exchange. Further development of the Agreement should be open for considerations and consultations among all concerned parties of the plant genetic resources community with a view for example to create the most open and effective possible system for the conservation, exchange, and enhancement of genetic material presumably under the aegis of a supranational authority. This model might be open to all public or private national or international institutes prepared to abide by the terms of the agreement and to provide a list of germplasm accessions to be exchanged under the conditions stipulated by the agreement. The excellent relationships of IARCs' with National Agricultural Research Systems and their Governments, and also with NGO, could be a favourable pathway to reach agreements on the model of the FAO-CGIAR agreement. Countries could agree, for example, to place their genetic resources into such a framework on the basis of prior informed consent. Access to samples and information of these resources could be unrestricted (subject to a legal mechanism) for all countries, which are parties to the agreement.

If conservation is important, it is of utmost importance to link conservation to use. Without strong linkages the value cannot be realized and eventually even conservation will be threaten. The issue of use however carries with it the problems connected with sharing rights (benefits) deriving from plant genetic resources. According to the principles embodied in the International Undertaking and reiterated by the Convention on Biological Biodiversity, and FAO World Food Summit, there is a need to ensure full respect of the rights of the countries in which agricultural biodiversity is found, and of their farmers and farming community, so as to avert the grave continuing danger of erosion of plant genetic resources and the irreparable loss of these resources.

As matter of fact, no concrete proposals have emerged up to now on giving practical meaning and content to the concept of farmers' rights as described by the International Undertaking as "an obligation to compensate farmers for their past, present and future contribution conserving and making available plant genetic resources".

Nevertheless, in contrast with the obligation of an equitable and tangible recognition of the farmers' rights, intellectual propriety rights and patent system regulations have received abundant attention and legal normative, as for instance items of interest to the biotechnology industry, like biosafety.

That is why the role of Farmers' Rights, a concept introduced by M.S. Swaminathan since 1979 in the FAO debates, and endorsed by FAO since 1989, is crucial (Swaminathan, 1995). They aim at reconciling the view of "technology-rich" and "gene-rich" countries in order to ensure the availability of plant genetic resources also for biotechnological industry within and equitable system. They aim at providing some balance to "formal" Intellectual Property Rights (IPR), such as Breeders' Rights and patents, invented to reward innovation acquired from the advanced research and resources invested in the industrial countries. Farmers should be rewarded no less than institutions and private companies.

Farmers' Rights and IPR need to be harnessed, in the interest of maintenance and use of biodiversity, of scientific research for the advantages for industries and farmers, after all for the human welfare, by developing agreements that promote the equitable sharing of benefits coming from a right use of genetic resources.

U.N. Agencies, like FAO, UNESCO, UNEP and UNDP, with the technical support of IPGRI and of CGIAR, could jointly develop *ad hoc* guidelines, in order to harmonize the provision of art. 27 (b) of the World Trade Agreement (regarding IPR) with the ethics and equity provisions of the Convention on Biological Diversity (Articles 8(j) and 15 of CBD). Such a revision of IPR will help to foster symbiotic biopartnerships, to protect biodiversity, and eliminate fears of biopiracy.

In this context, it is appropriate to remember that, in the frame of the patent system of inventions, which is mandatory for the World Trade Agreement (WTO), plant variety protection in industrialized countries is regulated by the Convention of the "Union for the protection of new varieties of crop plants (UPOV)", which recognizes and rewards only the breeders. In order to recognize and reward the contributions of farmer reserves as well as of breeders, a revision of UPOV to become for instance a Union for the protection of farmers (or, better, the farm communities) and breeders could be envisaged.

Thus an urgent action of Governments and international organizations is requested so that Farmers' Rights, so far considered in ethical and theoretical terms, might now be defined in legally binding terms.

Therefore, it is timely to put forward consistent and sound elements for enhancing the mutual supportiveness amongst the international fora, especially the CBD and the FAO Commission for Genetic Resources for Food and Agriculture from one side, and the Trade and IPR policies of WTO, the Trade Related Intellectual Property System (TRIPS) Agreement, the UPOV and the World Intellectual Property Rights Organization (WIPO), from the other one. Specular to such interforal cooperation, the best efforts should be spent in order to pursuit effective national systems and coordination mechanisms, by which negotiators in Trade and IPR conventions, while responding to their respective ministries and agencies, are aware and supportive of domestic policies and international positions embodied by officials negotiating in agricultural and environmental fora.

A contribution toward an improvement of the communication and the understanding both at the international arena and at the national level will take place into few days in Geneva, in a not-by-chance proximity with the TRIPS Council meeting, where the revision of the article 27.3(b) on IPR on biological innovations would be finalised. The organisers of the meetings are the Italian Agency, the Agronomy

Institute for Overseas (IAO) of the Ministry of Foreign Affairs, the South Centre, an inter-governmental organisation of the developing countries, and the Quakers, an international NGO committed with a range of equality issues around the world.

Thus, the Italian Government intends to contribute to an updated background study on the options for the implementation at the national level of the Farmers' Rights, with a focus on developing countries, according to the draft consolidated text of the International Undertaking. These proposals will be discussed within a panel of experts, and then presented to an audience of Trade and IPR negotiators from developing countries, involving also permanent delegates by OECD countries attached to WTO/TRIPS.

4. Conclusions

International co-operation in the field of genetic resources is imperative without delay. One of the most urgent issues to be solved, for political, environmental, scientific, economic and ethical reasons is the realization of the Farmers' Rights within the context of the revision of the International Undertaking and the development of a mechanism for its implementation. The revised International Undertaking could then become a protocol of the Convention on Biological Biodiversity.

Equity means equilibrium between public good and private profit, and in particular demands that developing countries receive benefit and compensation for the use of genetic resources that they host or hosted and partly already transferred on *ex-situ* collections in developed Countries and used by companies and breeders with beneficial results. Equitable and effective co-operation constitute one of the major mechanism by which resources of biodiversity can be conserved, managed and used sustainably all over the world, under legal agreements.

Among the first effective measures acknowledging of the rights of the indigenous farmer populations could be a formal statement of the industrialized Countries that part of any debt, to be remised and cancelled in favour of less developed Countries, should be used, according to specific rules of each country, for the farmers' communities. In this respect, it should be reminded that since 1988, Costa Rica has launched a very farsighted and ethical project: destination/utilisation of "debts for nature swap". This would compensate knowledge, innovations, practices of rural communities and consequently to re-examine, if not remove, among other measures, royalties on improved reproductive materials with final destination to the farmers' communities of territories rich in genetic resources, in which they "developed their distinctive properties", and are there conserved in *in situ* or *on farm*, or already collected and accumulated in *ex situ* gene collections.

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