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International Trends on the Conservation and Use of Plant Genetic Resources

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1. Introduction

First of all, a remark should be made that the central theme of this paper was derived from Watanabe and Raman (1997) [1], Watanabe and Iwanaga (1997) [2] and Rao and Iwanaga (1997) [3]. This paper is compiled from various sources of books which contain interdisciplinary ideas on social/political concepts, plant genetics and biotechnological aspects associated with plant genetic resources (PGR).

Crop genetic resource collections are assemblages of genotypes or populations representing plant cultivars, genetic stocks, and related wild and weedy species. They are maintained in the form of plants, seeds, tissue culture, *etc.* [4]. Functionally, plant genetic resources can include landraces, advanced/improved cultivars and wild and weedy relatives of crop plants (either domesticated, semi-domesticated or non-domesticated). Landraces are distinct local types, adapted to the many variations and interactions of natural and cultural environments in different regions of the world to which crop species have been gradually introduced. These landraces may contain coadapted gene complexes that have evolved over decades, making them location-specific [5,6]. Such landraces, sometimes referred to as folk varieties, are the most important for plant genetic resources. They exist alongside the indigenous knowledge of the people/communities that were responsible for their development. Additionally, advanced cultivars, especially those of recent origin, are also important resources. Most of these cultivars have been bred using a fairly large genetic base (locally adapted landraces) and hence may also have been incorporated into coadapted gene complexes from landraces. These, along with genetic stocks (natural or induced mutants, breeding lines with specific characteristics, accessions with resistances, *etc.*) also have a part to play in the future improvement of economically important plant species and therefore need to be preserved [4, 7, 8].

To appreciate the evolution of the work on plant genetic resources it is necessary to look briefly at the history of plant collecting. Though much exploration, plant collecting and introduction has been done previously, systematic work did not start until early this century. In the late 19th century, de Candolle initiated the conceptualization of the geographic distribution and origins of cultivated plants. The work of Nikolai Vavilov during 1920-1940 was a major milestone in the field of plant genetic resources. Vavilov described for the first time the 'centers of origin of domesticated plants' and theorized that one could determine the center of origin by an analysis of patterns of variation in plants in a region[9, 10]. This concept, which is more intuitive than empirical, has been much debated and modified [5, 11, 12]. but the basic outline remains the same. The main difference is what presently we think in terms of centers as well as noncenters that can hold genetic diversity of plants [12]. This concept is crucial from the point of view that the distribution of genetic diversity in plants is not random and has both spatial and clinal patterns. This influences the way we work with plant genetic resources, and our understanding of the utilization of the resources. The genetic diversity existing in various genepools of plant species has vast potential for current and future uses. To exploit this potential we need to make every effort to conserve and use plant genetic diversity safely and effectively for the improvement of human life and for the protection of the environment in which we live. The potential could be exploited either through conventional means or through the use of biotechnologies. In either case, plant genetic resources are the raw materials, without which no progress can be made.

The activities that relate to conservation and use of plant genetic resources include : germplasm acquisition ; characterization and evaluation ; conservation, assessment of variation and identification of useful genes; germplasm exchange and genetic enhancement. Acquisition includes collecting, which refers to gathering seeds or propagules of landraces, wild species, *etc.*, from the field and also to the assembly of materials through correspondence and exchange. The collected plant genetic resources have to be studied to understand their genetic structure and to identify useful traits. This is done by systematic characterization and evaluation of materials.

Conservation includes the management and preservation of known plant genetic resources. This takes two approaches, *ex situ* and *in situ*. *Ex situ* conservation maintains plant genetic resources outside the original habitat in facilities that have been specifically created, such as the seeds, field and *in vitro* genebanks or botanical gardens [4]. Plant genetic resources can also be conserved as pollen, DNA libraries, *etc.*, although at present the access time, *i.e.* the amount of time required to make use of the material, is inconveniently long. The infrastructural facilities required to hold resources with such methods also may not be within the reach of all. The other approach, *in situ* conservation, conserves ecosystems and natural habitats so that viable populations of species can be maintained in their natural surroundings. In the case of domesticated or cultivated species, this means the surroundings where they have developed their distinctive properties (as defined by Article 2 of the Convention on Biological Diversity). In either case, the enhanced use of conserved plant genetic resources to improve the standard of life of humans and to achieve a balance between sustainability and productivity becomes critical. To make the best use of the conserved materials, they need to be exchanged freely. This involves moving germplasm either in the form of seeds or other types of propagules, not only within a country but between countries. Finally, the plant genetic resources that have been collected, studied and conserved have to be used for plant improvement.

Use of plant genetic resources could be through simple selection from the materials that have been assembled or may involve the highly complex process of hybridization, testing, selection, *etc.*, depending on the genetic distances between the materials that have been used for the purpose of improvement. This process has been carried forward more recently with biotechnological methods. Here, we attempt to look in some detail at the role that biotechnology can play in conserving genetic diversity and in facilitating its use. We have not attempted to make an exhaustive survey. This is impractical because of the speed at which the field is progressing. We have also not tried to provide specific institutional details on any topic as these also may quickly become out of date. The emphasis is on the problems and opportunities that biotechnologies present for conservation and utilization of plant genetic resources.

2. National Policy And Institutional Framework

The Convention on Biological Diversity (CBD), which has been ratified by numerous countries, gives much importance to biotechnology associated with the conservation and utilization of plant genetic resources, and considers it as a means to enhance sustainable use and equitable sharing of its benefits. Hence it is appropriate to discuss the current situation as well as some future perspectives on this subject. Transfer of technology associated with PGR, including biotechnology, has been a key political issue for developing countries. A successful application of biotechnology at practical levels (National Programs), an institutional framework and national policies favorable to the practical application of biotechnology are needed. The individual characteristics of the world's flora and fauna are the basis of biotechnology. Individually, they produce the molecules on which biotechnology depends. These molecules have no other source [13].

It must be recognized that only diversity can allow sustainability. Only diversity can support social and economic systems to flourish, that allow the poorest to meet their food and nutritional needs as well as cultural diversity to flourish the world [14]. The biological resources of each country are important, but not all countries are equally endowed. The relative values of various resources are different. In general, it is well known that a few countries lying within the tropics and subtropics account for a very high percentage of the world's biodiversity. The CBD became an international agreement on 29 December 1993 when more than 30 countries ratified it. Issues related to technology transfer, funding mechanisms, intellectual property rights (IPR) and access to genetic materials are being discussed at various levels. There are strong proponents of IPR for genetic resources and their products as well as strong opposition to them at the conceptual level [15, 16]. The CBD encourages both access to and transfer of technology (including biotechnology) among nations, especially with developing countries. Access and transfer of any technology shall be consistent with the adequate and effective protection of intellectual property rights. Necessary policy measures shall be taken up to access and transfer technology on mutually agreed terms, as should plant genetic resources. Such measures shall assist joint development and transfer of technology for the benefit of both governmental institutions and the private sector organizations in developing countries.

The major problems that have been identified for transfer of technology as well as their adoption in the recipient country are : access to capital, human resources and support services ; intellectual property rights ; regulatory issues such as biosafety and exchange of information and knowledge ; environmental concerns and transaction costs [17].

The CBD encourages countries to take legislative, administrative or policy measures to handle issues related to biotechnology and the sharing of its benefits on a fair and equitable basis. Countries may be required to set up appropriate procedures (such as codes of conduct) in the field of the safe transfer, handling and use of any living modified organisms resulting from biotechnology that may have an adverse effect on the conservation and sustainable use of biological diversity. National committees may be set up to discuss and recommend the necessary measures. The need for providing any available information about the use and safety regulations in handling such organisms (biosafety regulations), as well as available information on the potential adverse impact of the specific organisms is recognized.

Broadly speaking, benefits of biodiversity for the biotechnology industry can be twofold. Firstly, biodiversity significantly lowers the research and development costs of the industry since it serves as a highly productive *in-situ*-stock of genetic material [18]. The potential uses of biotechnology for conservation are many and one of the most important is in the context of making conservation and use of plant genetic resources cost-effective [1, 3, 19-23]. For the implementation of the CBD, it is essential that the benefits overtake costs and thus conservation becomes attractive to policy makers. Additionally, biodiversity represents insurance for agriculture because it diminishes the risks of productivity variations as it can rely on many instead of only a few cultivars [24-30]. The preferential technology, including biotechnology, basically means that the developing countries will at least partially be able to circumvent license fees without risking any sort of retaliation [31-33]. This arrangement may be looked at as an essential mechanism for donor support to biodiversity conservation [34]. For fairly detailed discussion of several issues related to technology transfer, national policies, areas of application of biotechnology, *etc*., see Altman and Watanabe [17].

3. Public Awareness and Intellectual Property Rights (IPRs)

Among the international discussions, the nationalism on PGR, especially the protection of IPRs such as the patenting of the plant varieties has been a global and complicated concern which cannot be sorted out simply among related parties and nations [34]. However, it seems that the importance of the value of PGR is not well recognized by the public compared with the recognition of other natural resources such as water, air and energy ; The Japanese public is no exception [35]. PGR is not only the components of important natural resources, but also has strong links with environmental conservation matters. For example, the tropical forests consist of a complex of plant species, which are essential for the conservation of ecosystems and self-remediation of the ecosystems by plants [26]. Thus, the value of PGR is exquisite for the present and the future [1-3, 26, 27, 30].

In contrast to the overwhelming interest among various sectors and individuals in Japan in the initial Environmental Summit held at Rio de Janeiro in 1992 which included the conservation and sustainable use of biological diversity, there is very little attention paid to the on-going meetings of the Convention of Parties (COP) associated with the CBD [36]. On May, 1998, COP-4, the fourth meeting of the COP, was held at Slovakia. However, it is a pity that there was not much participation by Japanese groups compared with the Rio Summit, although one fifth of the proposed budget which is equivalent to USS 50 million has been pledged by Japanese government to CBD [37].

A specific example of the current situation on the IPR with PGR, with respect to profit-oriented interests of specific groups follows. Bolivian quinoa was patented by US professors : Quinoa (*Chenopodium quinoa*) is a small grain species which is rich in protein, and is very common and important in the diet for the people of the Andean region. In developed countries including Japan, quinoa is used for diet food in regular markets and is becoming economically important. The use of F_1 hybrids to make cultivars has been considered, and the production of seeds for these cultivars has been profitable in the US and European seed business. Professors at the University of Colorado patented the male sterility trait derived from Bolivian quinoa, Apelawa variety for F_1 seed production in 1994 (US Patent 5304718) [38]. This patenting has damaged the traditional use, production and ownership of Andean users, because of the potential of forbidding and fining the exportation of the quinoa variety from the Andean region to USA as the infringement of the US patent.

The above type of nonsensical patenting issues and extremely biased protection of IPRs are associated with the following undigested matters in societies [1-3].

1) Lack of number of legal specialists : There are few patent attorneys with in-depth knowledge on PGR and biotechnology compared with the actual

needs. In the case of Japan, there are less than ten patent attorney offices which can handle the legal and technical matters associated with PGR and biotechnology. Also, the total number of patent attorneys in Japan is extremely small in contrast to the skyrocketing increases in IPR protections. In a similar way, not many exclusive specialists are available in plant protection laws [39]. Human resources development in this area is essential in winning or even protecting the national interest and industrial development.

2) Bioethics : The recognition of the ownership of and benefit sharing from the PGR must be considered before discussing the legal matters. The concept of equitable IPR should be the key issue for making a globally fair distribution of benefits from the PGR. This should not be recognized only by scientists, but also by the general public as to their rights as the potential recipients of the benefits from PGR.

3) Public awareness : Thus, the public enlightenment on the value and rights towards PGR should be widely introduced especially in the industrial sectors which should consider returning the contribution back to the parties/communities where the beneficial PGRs originated. This is not only from the views of benefit sharing but also from the philanthropic view which must be considered.

The understanding of the above subjects will lead to working with the nations/parties which can have strong chain on the ownership of the PGR [40]. Now, many countries with rich diversity and/or are the origin of the species of interest require legal documentation to access PGRs ; Germplasm Acquisition Agreement (GAA) and Material Transfer Agreement (MTA) together with Export Permit/Certificate should be prepared in any international transaction in the movement of the PGR. Thereby, the parties which do not follow the procedures will be in legal violation internationally as well as accused publically. However, due to the slow process of the negotiation of the international treaty under CBD, it may be more difficult in the short run for the physical movement and use of PGR in plant breeding or other associated disciplines as many countries become sensitive and protective on the matter. An immediate consensus is desirable, however, in the reality of international dealing, this will not happen. The international political turmoil and extreme profit orientation by the private sector on PGR may contradict the efforts towards alleviating the food and population problems in the 21st century [41].

4. Conservation of Plant Genetic Resources in Genebanks

The conventional conservation of PGR has been conducted *in situ* by local communities and small-scale traditional farmers [19, 21]. In contrast, the genebanks also have been engaged in preserving collections *ex situ*. [19, 28, 29]. Here, biological aspects of the preservation of the PGR at genebanks shall be highlighted for the many species which need more basic information.

A. True seed propagated species :

The following subjects are important for further research [22] ;

1) Physiology on flowering and seed propagation ;
2) Physiology of seeds for long term storage ;
3) Population size and change in allelic frequencies on rejuvenation of seed generations ; and
4) Increasing chance in recalcitrant species , especially in the tropics [42] ;

Especially to determine the amount of seeds to be preserved, these two issues also have importance : 1) Duration of the period of seed storage in each seed generation and statistical probability on viability and 2) general genetic diversity and preservation of specific alleles of interest [20]. Under common recommendations, a large amount of seeds per accession shall be maintained, on the other hand, an enormous number of accessions should be preserved at a genebank, so critical mass for the maintenance of each accession should be another factor for the PGR preservation at a genebank. Unfortunately, the reality of the genebanks is far from the desirable condition due to the shortage of sufficient financial back-up. At many genebanks, there could be genetic erosion taking place due to managerial factors principally attributed to the insufficient funding supports. An example of typical crisis is the present situation at the N. I. Vavilov Research Institute for Plant Industry at St. Petersburg, Russia, which used to be the top-notch PGR genebank. However, now it is facing financial crisis, consequently there is danger of the loss of precious PGR collections [2].

B. Vegetatively propagated and/or perennial species :

The following subjects shall be further studied for more effective management of the clonally maintained accessions [2, 3].

1) Rooting capacity in woody species and epiphytes ;
2) reduction of somaclonal variation in *in vitro* preservation ;
3) duplicates identification ;
4) genotype independent tissue culture methods ; and
5) cryopreservation, especially for tropical species.

5. Conservation and Use of the Plant Genetic Resources towards Sustainable Industrialization with Biotechnology Applications

The primary use of the PGR in the industry is for the production of basic materials. Planned production in plantations and agriculture fields would be less damaging than collection/harvest from natural reserves, although as yet serious environmental concerns about pesticide uses and erosion exist. As well as agricultural plant species, it should be recognized that a gradual shift from slash-and-burn of the tropical forests to a scheduled and systematic production has been taking place. This is based on mass production of propagules through the application of micropropagation to the industrially interesting species and extensive public education of the *in situ* conservation and use of natural forests [21, 26]. On the other hand, only a limited number of species can be employed by such a system due to an unavailability of specific technology relating to particular species [1-3]. Also it shall be remarked that an extreme bias of the selection of or monoculture of cultivars/species always results in genetic erosion, thus, a strategic use of the technologies should be accompanied by sustainable uses of PGR harmonized with the genetic conservation.

With the advancement of basic research and development in the plant sciences and technologies, the following categories should enhance the conservation and use of the PGR [2].

1) Mass propagation by tissue culture for conservation.
2) Photo-autotrophic micropropagation on a large scale for industrial propagule production.
3) Immunological or molecular biological tools for detection of plant pathogens and pests in plant quarantine and genebanks. A measure for the quality of commercial propagules.
4) Detection of environmental toxins/pesticides in *in situ* conservation.
5) Molecular markers for the evaluation of genetic diversity and genetic erosion [43, 44].
6) Molecular biological approaches to isolate and utilize plant genes in genetic engineering.

The above categories are being used for some specific cases, however, it is needed to accelerate the basic research for tropical plant species which have a lot of missing information and require refinement of the technology application.

Further exploitation by basic research should be encouraged in the following areas for systematic industrial utilization of PGR [2] ;

1) Extensive survey of the genetic diversity and specific chemical substances of industrial interest other than major crop species ;
2) Survey of the relationships between the pesticide residues and conservation of PGR, and development of agrochemicals with low residue and low toxicity as often landraces and wild species are more sensitive to agrochemicals than modern cultivars ;
3) Low cost and low profile tissue culture system for small scale industry ;
4) Mass production methods for elite clones for large scale industrial purposes instead of slash-and-burn type uses.
5) Preservation methods for recalcitrant seeds in true seed propagated species ;
6) Strategies for seed collection and propagation with the view of population genetics for the conservation of genetic diversity, especially on outcrossing polyploids ;
7) Databases for plant pathogens and pests including biology, epidemics, diagnostics and protection methods, a molecular plant x pathogen/pest interaction, chemical ecology and integrated pest management should be emphasized on the basis of sustainable industrial production based on resistant cultivars and management methods based on them ;
8) Screening methods for chemical components, particularly for pharmacognotic uses ; and
9) Transformation processes and cost-down for new industrial materials such as bio-degradable plastics made of plants.

6. International Collaborations and Networking on Plant Genetic Resources with Biotechnology Applications

So far, we have discussed the role of biotechnology in the conservation of plant genetic resources and their enhanced utilization for crop improvement. We have also stated briefly the various technologies available which can help either in single application or in combination for plant improvement workers to achieve results that have not been possible through conventional techniques, or which used to take long periods. One major theme that can be seen through all the discussion is the multidisciplinary nature of both biotechnology and plant genetic resources. They are both made up of a number of sometimes overlapping disciplines. Such a multidisciplinary nature requires excellent cooperation among all concerned for the successful use of the tools for utilization of the resources available. This is especially true when the issue of transfer of technology is concerned. To make the transfer more effective and to ensure equitable sharing of profits, a multilateral collaboration is more desirable. This logically leads us to networking. We will discuss a couple of examples here of how such networking can be taken forward, in relation to plant genetic resources and their utilization. However, it must be noted that the networks under consideration are not those formulated for biotechnology work but for genetic resources management purposes. Within this scope, efforts are under way to link up the network members in using biotechnological tools for the study and use of genetic resources.

The International Plant Genetic Resources Institute (IPGRI), with financial support from the government of Japan, is an active partner in the International Network on Bamboo and Rattan (INBAR) and is mainly concerned with the PGR aspects of INBAR through its Working Group on Biodiversity and Genetic Resources. Here we consider rattans or canes, which are unique group of climbing palms in tropical rain forests. There are more than 600 species in 13 genera, *Calamus* (400 species) and *Daemonorops* (115 species) being the largest [45]. Millions of people in the tropics depend on rattans for their livelihood. As there are numerous species of rattan it is not possible to work on all of them. Some level of prioritization is required to undertake activities on rattan plant genetic resources conservation and use. Initially the species on which work will be carried out is determined [45], through consultation of the network members, assisted by resource persons. Along with priority species, some activities were identified, including assessment of the status of rattan genetic resources, assessment of the degree of threat of genetic erosion, conservation priorities and the development of a database with applications of modern biotechnology. There is need for a clear taxonomy and a simple practical key for species of economic importance. Studies focusing on genecological variation and genetic diversity are in progress, with possible linking with training. Ethnobotanical studies focusing on the traditional knowledge and management of rattan need to be developed. Assisting in exploration and collecting of rattan and conduct of ecogeographic studies are essential. There is a need to develop technology for long-term conservation and utilization, including *in vitro* culture methods for *ex situ* conservation [45]. Development of sustainable *in situ* conservation strategies for these species is another area that needs urgent consideration. This would require an assessment of *in situ* diversity using molecular markers before such methods could be used for improvement purposes. Within the network of INBAR, in partnership with national programs such as Thailand, and linkages with advanced institutes in Sweden, IPGRI is supporting the study of genetic diversity in rattan [46].

Other examples are International Coconut Genetic Resources Network (COGENT), INIBAP (International Network for the Improvement of Banana and Plantain) and SGRP (System-wide Genetic Resources Programme-CGIAR) which are under auspices of IPGRI or joint coordination by IPGRI and sister International Agricultural Research Centers/International Genebanks [2, 3]. These mentioned networks represent well the national and international communities that share information, activities and common concerns. A USA based alliance made mainly of universities, GREAN (Global Research on the Environmental and Agricultural Nexus for the 21st Century) has strong connections with the above networkings by providing research opportunities for graduate students and university faculty members and direct human resources contribution from their higher education programs [47].

On the other hand, irrespective of the amount of financial contribution made to these networks from Japan mainly via the Ministry of Foreign Affairs, there is very little human resources contribution to these international networkings. However, it should be recognized that JIRCAS, Japan International Research Center for Agricultural Sciences, and JICA, Japan International Cooperation Agency, have their own bilateral activities on PGR, and they may be the best starting points for the international efforts. Also an academic institution based initiative may be coming out as the precinct activities under "Research for the Future Program" (RFTF) which is financially supported by Japan Society of Promotion of Sciences (JSPS). Not only the critics of the present weakness, an encouragement should be made to academic/public and private sectors in Japan to eliminate the selfish exploitation of the PGR in industrial utilization. In considering the past contribution, overall future values and the specific industrial potentials of the PGR, the private sector which uses the PGR for their own business and profit should contribute and share the benefits in lights of global needs. For conceptual guidance on such international collaborations shall be referred to Bunting [48], Iwanaga [49] and Tompson [50].

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