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In situ Conservation of Plant Genetic Resources—Some Global Perspectives*

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The global perspectives of in situ *conservation are discussed with emphasis on crop and forage genetic resources. The parts of the gene pools vary according to how they contribute useful variation. In some crops high priority is allocated to wild relatives. Various complementary methods of conservation are dealt with. It is stressed that pragmatic decisions need to be taken up case by case, as done by IBPGR with clonal crops. The amount of efforts to be placed on* in situ *conservation will vary from it only being a small component in the case of tropical root and tuber gene pools to being the major component for rubber, cacao and many fruits. The urgency in the study of genetic diversity for* in situ *conservation sites, biosphere reserves, etc. is highlighted. The need for a minimum level of understanding of diversity patterns as a prerequisite for sorting out biosphere resources is stressed. Scientific planning is required in collection, conservation vis-a-vis management of this diversity. IBPGR's role in this context is highlighted and the need for training more personnel stressed.*

In this paper, a number of global perspectives for *in situ* conservation of plant genetic resources with examples largely drawn from crop and forage genetic resources are discussed. For samples of crop germplasm and their wider genepools, conservation *in situ* is probably neither justifiable scientifically for the domesticates, i.e. the array of variants produced by man, nor justifiable for the weedy relatives associated with disturbed agricultural environments. From the point of view of the broad crop genepools, this leaves wild species related closely or more distantly to the crop plants. Scientifically, it could be argued that such wild species are best left in the field in their natural environments unless they are under threat and there is a justification for their conservation *ex situ*. For instance, there is a need by current users, plant breeders and other scientists, for readily accessible collections *ex situ*; especially when in nature, these wild species are distributed over wide areas or are to be found only in remote and inaccessible places. In such situations, the collections referred to comprise samples which are usable or useful. The wild relatives, find their utility in breeding.* In the main, they are used as sources of genes rather than as adapted genotypes. There are always cases when crop expansion

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into new or marginal areas is a breeding aim and in such cases, which are relatively few, adaptations might well be important. With respect to forages, the collections have been and will continue to be used for adaptation more than as gene sources. Such distinctions are extremely important in considering the conservation, maintenance and utilisation procedures of these *ex situ* collections. For instance, accessions of the wild species related to major staple food crops might well be considered as genetic stocks rather than populations. Many old collections of forages have by their maintenance lost adaptations for which they were originally collected and future maintenance practices of newly collected materials could well have to consider cloning via tissue culture.

Another distinction requires consideration and that is the level of sophistication of the breeding of crops. The major staples are already using the tertiary genepool in breeding but many industrial and fruit crops (and forest species) represent simple selections from the wild and even if progeny have become semi-domesticates, they cannot be regarded in the same way as the landraces of cereals, food legumes and others. Yet another consideration relates to the life form of the species. Conservation of wild annuals *ex situ* presents less problems than that of wild perennials but the strategy for their conservation *in situ* would be very different. Many annuals are associated with ruderal environments with which nature conservation practices cannot easily cope.

IN SITU CONSERVATION—A PERSPECTIVE

These points lead to the need to define a series of objectives, each with a scientifically-based strategy in order to consider sensibly *in situ* conservation. The time is long past when generalisations can be made simply because the overall idea is sound. In this respect we have a paradox among the international interests in conservation.

When the genetic resources movement was gathering momentum in the 1960s, the nature conservation movement remained aloof and did not lend its voice in support. Now the justification for all types of plant conservation seems to use the need to conserve genetic resources, whether in an attempt to preserve species which might one day be found to be useful or attempts to use under-exploited plants. Many of these justifications are not based on the clearest scientific thinking and genetic resources have become something of a bandwagon muddied with political undertones and spurious claims.

I believe that conservation of plants is in itself a good thing—whether of species, ecosystems or populations of useful plants. The plant life of this planet is indeed a heritage and my attempts in the past few years in many fora of the wider conservation movement have been to try to put in some sound science into the thinking and to thereby avoid competition for sources of limited funding. We are now faced with a number of international agencies and organisations all involved with plant conservation in one form or another and it is the duty of all of us to see that maximum benefit is derived from our actions. In the case of my own organisation i.e. the International Board for Plant Genetic Resources, we are in a privileged position in that we developed from a long history of solid scientific thought and effort and still maintain a policy of relying on scientific input rather than on politics or philanthropy.

Target species for in situ *conservation*

With reference to crops, the parts of the genepools to be conserved vary according to how they contribute useful variation. Certainly not all aspects of variation will be of value to agriculture and a wide understanding of this on a crop by crop basis is necessary before considering the urgency of *in situ* conservation. However, there are cases where there is a high priority for *in situ* conservation of crop relatives. These include the wild relatives of the perennial vegetatively propagated crops and, in several cases, seed-producing forages and wild grasses of the tertiary genepool of cereals. Examples of the former include rubber, cocoa, coffee and many tropical fruits. Even taking into account these genepools, there are in fact, few related to staple food crops which will continue to rank highest in priority for action. Of course, forest species will always continue to rank high for *in situ* conservation as will others associated with fuel, shelter and fibre. I have purposely not mentioned landscape amenity but it should be understood that all *in situ* schemes need to be associated with more sustainable forms of rural development, and estimates of indirect benefits through watershed maintenance, wildlife habitats and environmental stabilisation.

As breeders are quick to point out, it is not always easy or convenient to use wild species. Hence vast schemes to preserve *in situ* such materials may never receive support. Nor will support be forthcoming simply because material might prove to be useful hundreds of years from now. Rather than try to argue such cases, it is easier to lend support to the need for ecosystem conservation, knowing that in the process, some useful material related to crops will be conserved.

This composite approach is considered essential. The past two decades have provided countless examples of reserve areas being designated for wildlife habitats alone or forest ecosystem conservation alone. We are in a situation where only about 10% of reserve areas have been inventoried for their plants. When all have been inventoried, we may well find out that many of them will in no way serve properly the multi-purposes they should do. As reserve areas are the responsibility of national governments, the compilation of inventories and the funding of scientific work in these areas will continue in many countries to be in conflict with more pressing development needs such as education, health or road building.

COMPLEMENTARY METHODS OF CONSERVATION

For most species genepools whether forest, crop or others, there are a number of complementary methods of conservation whether *in situ* or *ex situ* in seed, in *in vitro* or field genebanks. Pragmatic decisions need to be taken case by case as indeed IBPGR has done with clonal crops. In many cases, the major conservation method will be *ex situ* as seed, even if heterogeneous, backed by a limited number of clones in field or *in vitro* genebanks. The amount of effort to be placed on *in situ* conservation will vary from it only being a small component in the case of tropical root and tuber genepools to being the major component for rubber, cacao and many fruits.

Where it becomes a major component, the prerequisite for action is an understanding of the genetic diversity of the genepool. In many, if not most cases, there are incomplete or not very effective taxonomies in existence. If vast areas could and would be conserved, this would not matter greatly but when choices have to be made of restricted and specific areas, it is essential that there be sufficient number of plants and sufficient genetic heterozygosity to permit adaptive responses. Knowledge of areas currently with the highest species diversity cannot automatically be used as a basis on which to work. Evidence may well be that areas with lower species diversity but with substantial genotypic diversity may be equally important. However, survival requirements of plant species have largely been ignored in debates on designs of reserves. The need to define a minimum reserve area for a particular species, which is linked to minimum population size, is an essential preliminary part of the planning.

Since we lack data on most of these points, it is clear that we need a number of scientific surveys and analyses in areas such as the Amazon on the tropical rain forest in Southeast Asia to use as models for reserve design and provide data for when *in situ* conservation will be the primary method of conservation. We shall then be in a position to designate real genetic reserves.

DIVERSITY AND DESIGNATION OF RESERVES

About five years ago, scientists began trying to understand in broad terms the concepts as applied to several aspects of natural systems. As Schonewald-Cox (1983) pointed out, the term diversity is used for species diversity, allelic diversity, allelic frequency difference between individuals within and between populations and a combination of species diversity with allelic variations. Even so, conservationists largely think in terms of species diversity based on inadequate taxonomics and do not consider aspects of the long-term survival of species. In practice, both species diversity and allelic diversity are important to genetic conservationists, whether foresters or crop breeders.

Such problems stemming from a lack of information might well be overcome if reserve areas were to be based on assessment of the maximum number of heterogeneous ecologies within the distribution of a species. Then on the basis of evolutionary theory, there is a chance that a range of ecogeographic variation should be encompassed, thereby ensuring long-term survival. Ashton (1981) proposed the mapping of species and populations along environmental and ecological gradients so that distribution can be related to them.

I return to the need to survey diversity at the outset rather than trying to do it years after reserve areas have been established. We, in IBPGR, are particularly interested in this because we have to identify target areas for collection of germplasm for species which might encompass the whole Amazon basin and adjacent areas (e.g. cocoa) or every sub-Saharan country of Africa (e.g. wild *Vigna* related to cowpea) and it is necessary for effective field work and collecting. We have discussed, and might well implement, a survey method which covers a very wide area using a grid system and at each site sample specimens for analysis by biochemical/molecular methods (isozymes; RFLPs) and numerical taxonomy. This could provide a degree of resolution hitherto not available. We might then be able to think of centres of diversity for specific wild species of value for genetic conservation and many of which clearly fall outside the Vavilovian crop centres. Strategies for conservation, *in situ* or *ex situ*, might then encompass populations spanning marginal or outlying populations if evidence suggests they might be useful.

We know a lot about diversity even if no single measure serves every purpose. After all, diversity is an evolutionary product and many such products are difficult to measure, e.g. intelligence or phylogenetic relationships (Whittaker, 1972). We do know, however, that diversity follows certain patterns. In vegetation, measured in terms of species, it increases during successional changes and can also be combined with relations of diversity to environmental gradients (Auclair and Goff, 1971). So too is the diversity of a species within habitats related to the total or gamma diversity of communities with differentiation of all interacting species to fill niches. There is thus a time aspect to understanding diversity related to stability aspects of the environment which leads to genetic flux in populations in response to competition and periodic resource shortages in microsites. Hence, our measurements of diversity must be based on populations and not on single or a few selected specimens.

I suspect also that our delimitations of diversity in wild species differ in terms of definition or emphasis from those for landraces of crops, especially in terms of selection pressures, seasonal variations and other aspects of the latter. We know little about the nature or extent of diversity over a period of time in natural populations, except that the evidence supports the hypothesis that genetic polymorphism and heterozygosity are indeed correlated with environmental heterozygosity; isozyme analyses have supported this (Nevo, 1978).

I have stressed the need for a minimal level of understanding of diversity patterns as a prerequisite for the designation of reserve areas. The next step is to integrate such desiderata with other protected areas. Clearly, the reserve cluster *sensu* IUCN and a complex of various categories of protected natural areas can often act as a large spatial unit which minimises the import of landscape fragmentation and ecological disintegration (McNeely and Miller, 1983; Soule, 1983). Without such consideration, land use in surrounding areas can have a major influence on the designated conservation area. Ingram and Williams (1984) have mentioned the debate which continues on design of reserves, especially of their area and shape and the advantages and disadvantages of large contiguous areas or combinations of smaller areas; but data are derived from animals rather than plants.

I do not propose to go into aspects of costs nor accessibility for collecting germplasm for use but we must not lose sight of the need for some security, some management and some scientific monitoring of plant populations over a period of time. This implies organisational infrastructure, trained personnel and continuing financial and political support for reserve areas comprising often several countries and compatible with regional development. Frequently the genetic reserves will only be parts of these wider schemes.

These needs pose major problems in parts of the world where the climate of opinion is not conducive to nature conservation and where there is often resentment that scientists from other more affluent parts of the world tell people what to do. It is no wonder that questions begin to be asked about who benefits from the efforts especially when the philosophy encompasses mankind and his heritage.In part, the fault lies with scientists who passively allow the division of labour among numerous organisations and leave discussions on common scientific principles to such organisations.

TRAINING NEEDS

If the clue to better conservation lies in science then the basis must be the acceleration of suitably-designed training. *In situ* conservation is so wide and so inter-disciplinary that specific training is needed as a matter of urgency, particularly for scientists in developing countries.

Here a lesson can be learned from the history of crop genetic resources over the past two decades. International activities and the development of concepts through the widening of the research base was backed at the outset by training. We are at a stage where the science is sounder than hitherto and where we can consider intercalating streamlined management practices to increase effectiveness.

Yet crop genetic resources activities have only formed a small part on the total efforts devoted to conservation. So many of the wider efforts lack the solid backing of appropriate training.

When the World Conservation Strategy was released in 1981, it proposed a combination of *ex situ* protection for all economic plants whether crops, forages, forest species or others. When an economist made a critique (Tisdell, 1983), he rightly pointed to the question of costs not being discussed. In relation to costs, at present, only about 1% of the total expenditure globally on crop genetic resources relate to training and this has proved to be most effective. In the case of native conservation, an allocation of up to 5% of the current expenditure would support new post-graduate courses which could quickly form a cadre of scientists able to work in an interdisciplinary way to promote, enhance and staff reserve areas.

Although we are always watching the clock because of too rapid genetic erosion of crop, forage or forest genepools or, indeed, species extinction, the creation of this new generation of scientists before the turn of the century would go a long way towards ensuring scientifically-designed conservation especially if the scientists were to carry out research on the complex array of populations which comprise taxonomic entities.

TYPES OF RESERVES

The types of networks of genetic reserves needed, have been listed by Ingram and Williams (1984). They are :

1. Biosphere reserves: as defined by UNESCO: Man and the Biosphere programme. These include reserves and national parks in which many economic plant relatives are present. Critical needs include data in readily accessible data-bases, expansion of the network and targeted research on specific plant populations. Such reserves will be a suitable primary method of conservation for many woody species, tropical crops and/or their relatives, e.g. coconut, cacao, taro, breadfruit, citrus and many tropical and temperate fruits. FAO has initiated pilot projects specifically for forest species based on commercial species with wide natural distribution range and under heavy utilisation pressure, species with limited distribution range but under pressure for changes in land use; and species endangered with extinction in the country. So far these pilot projects are only in operation in Cameroon, Malaysia, Peru and P. D. Yemen.

2. Special-purpose reserves especially needed for usable resources, e.g. screening of disease resistance in areas where they are endemic.

3. Special purpose reserves to expand or fill in gaps not covered by regionally or nationally-oriented reserves which have been designed for specific species or ecosystems which are endangered. These should target special parts of plant genepools to fill gaps known from the inventory data bases.

4. Specially-designed networks of reserves for widely distributed genera where diversity in the genepool is not understood, e.g. *Allium*, *Vitis*, *Syzygium* (clove) and many trees where there are scores of related species. It is noted here that these will aid availability of resources which are not easily available to users (Harlan, 1976).

Such reserves will be based on descending priorities :

1. plant is of major international significance;
2. plant is of regional interest;
3. plant is thought to be of potential interest in the future.

LINKAGES BETWEEN *EX SITU* AND *IN SITU* EFFORTS

To predict other than broad generalisations it is necessary to consider the use of the materials. On the one hand plant breeders will continue to use the readily available and better-known samples such as the landraces of crops. Now that a great deal of the remaining variation of landraces is in collections, it is necessary to know the material better. Similarly, foresters will opt for "desired diversity" (Namkoong, 1983) rather than unknown materials. With newer molecular techniques the usable part of the genepools gets wider (but wider does not mean there will be a wholesale shift by plant breeders to use of this part of the genepool as a matter of routine). Such plants will continue to act as a back-up resource well into the future. Hence, it would be futile to try to carry out economic assessments of the value of species in *in situ* reserves for crop or forest improvements. For instance, it is meaningless to say that coffee generates more than $10 billion per year in foreign exchange earnings for Third World countries and therefore, some of this should pay for *in situ* reserves. In fact a molecular biologist is more likely to take and transfer a gene from a totally unrelated plant ready to hand (or already extracted) than to wish to sample a distant wild relative in a remote reserve.

However, some species will be used much more effectively, especially when the domesticates are little more than selections from the wild. This will certainly be the case with numerous woody species whether for timber, fuelwood, browse, or fruits and for certain cash crops such as cacao. It will also be the case with most forages.

The distinction is therefore, going to remain as to whether *ex situ* or *in situ* conservation remains the primary method. *In situ* conservation requirements are not, in any way, going to act as an alternative to or a replacement for the *ex situ* methods, certainly for crop plants.

In the context of nature conservation there is a case to be made for endangered species being conserved *ex situ* so that repatriation could be carried out in the future. Certainly the history of maintenance of rare species as semi-domesticates in botanic gardens has not been very effective due to the narrowed genetic diversity and altered selection pressures (Frankel and Soule, 1981; Raven, 1976). New initiatives through IUCN are now underway which will lead botanic gardens to consider conserving populations rather than specimen plants.

CONCLUSIONS

Genetic resources of economic plants are likely to be needed much more in the foreseeable future than in the past. The reason for this is that concern has surfaced for developing environmentally-sound and sustainable agricultural systems. For instance, use of agroforestry mixes, fuelwood species for soil stabilisation will be more widespread and there are changes in the pattern of requirements and sources of cooking oils and fodder.

Our responsibilities are clear : we have to see that as much diversity is conserved as possible and that it is freely available to all who can use it since man's survival depends on it. This is our prime responsibility which must be paralleled by our concern for all plant life and the maintenance of the planet's heritage.

These responsibilities can only be met when it is recognised that sound scientific planning is necessary. Here this will translate into a two-pronged operational strategy : firstly, where data exist on crop relatives and where there is an understanding of their role in the ecosystems; secondly, where these data are lacking and there could be holding operations in parallel with research. Trained manpower is critical both to the management of the former and resolution of issues for the latter.

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