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Chapter 54

Conservation and Use of Plant Genetic Resources

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54–1 PROTECTING THE GENETIC LIBRARY

Comprehensive protection of genetic resources must be implemented in response to scientific strategies based on our increasing understanding of the complexity of species biology. Without sound scientific approaches to conservation, organizational strategies will fall short of ensuring the protection of the very species they were established to protect. Sound scientific strategies are needed to guide conservation efforts from germplasm acquisition to management of collections at the national and international levels. This will necessitate integrated approaches to comprehensively protect the genetic library represented by global plant genetic resources, including greater interaction between scientists working at the three levels of biological diversity: genetic, species, and ecosystem.

Of the three levels which comprise global biological diversity, genetic diversity has received the greatest attention within the agricultural community. Genetic diversity refers to the total genetic information contained in individual plants of a species, each containing a unique assembly of genes constituting its evolutionary heritage. This diversity begins at the molecular level, is carried as sequences of instructions on chromosomes, and provides a foundation for environmental adaptation and ultimately for the evolution of species.

This focus on genetic diversity and its application to modern crop improvement allows for manipulation of genetic diversity within time (Duvick, 1984). However, a focus on genetic diversity and ex situ collections alone is not adequate for the needs of global agriculture. For conservation of genetic resources to maintain its relevancy, greater understanding of the remaining two elements of global biodiversity, that of species and ecosystem diversity, will be needed. These components offer the potential for diversity in place as opposed to time.

The need for integrated conservation strategies can lead to confusion regarding the types of conservation approaches available, largely because the term 'genebank' has come to be equated with the refrigerated seed store. Ex situ samples may be conserved as seed, cultured cells or tissue, or growing plants. In situ may involve a target species as a component of an ecosystem without genetic management or a specific genetic reserve with management intervention.

Integrated conservation considers a range of conservation resources and methods for use, depending on the type of genepool, or biological entity of concern (Falk, 1990). In the case of crop plants, which have immediate utility, most are amenable to seed storage. Some require complementary in vitro conservation, and with others, orchards are used as field genebanks. Not all are suitable for long-term storage.

An additional responsibility rests with the international community to ensure that national programs relate to international interests based on commodities. Collections maintained by commodity-based International Agricultural Research Centers (IARCs) represent the latter, whereas national collections represent a spectrum of diverse activities related variously to plant introduction, local conservation, and plant breeding. Some are large, integrated, multi-crop programs, e.g., in India, China, Brazil, Russia, and USA; others are related to very few crops; and others are solely collections of plant introductions. The Food and Agriculture Organization of the United Nations (FAO) Commission on Plant Genetic Resources presents one means to re-frame national program aims, assure operating funds, and provide global linkages.

Many programs will be viable into the future; others may fail, so the security of collections, long a strategic aim of the International Board for Plant Genetic Resources (IBPGR)

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will become vitally important. Storage facilities will be transformed into real genebanks, fully functioning with necessary regeneration, documentation, and evaluation procedures in place. Many programs are operating at functional capabilities and are unable to systematically meet user demand. This illustrates a major gap in the international system. Investment should not be in many more genebanks but in their management and efficiency. Nor should this central theme be diluted by spending more on creating public awareness or in schemes for on-farm conservation of primitive forms until there is indeed global security of the staple food-crop germplasm and representative collections of other plants.

54–2 MOVING TOWARDS CONSERVATION COLLECTIONS

A more integrated approach to conservation which encourages the inter-relation of systems mentioned above would allow a more comprehensive conservation program to emerge. In so doing, ex situ collections become conservation collections, defined as collections comprising representative genetic samples of species according to the best available scientific understanding of the species' population biology. They are maintained in one or more forms (such as growing plants, seeds, and tissue culture) and curated for permanent maintenance (Center for Plant Conservation, 1991). Adoption of collection and management guidelines will be necessary in updating ex situ collections to conservation collections and to ensure their emergence into an international system that takes advantage of multiple conservation methods. Present tasks include:

1. Sort out collections which conserve materials already well conserved and duplicated elsewhere, remove redundancy.
2. Make collections more representative of the patterns of genetic diversity in the crop genepools.
3. Provide better scientific standards and guidelines for all aspects of collection management.
4. Develop management guidelines for strategic planning, funding allocation, and cooperation with other programs.

These all rely on good documentation systems integrated across programs and based on individual commodities. For instance, sorting out of samples can be done when it is known who stores what, and redundancies can be identified. Site collection data and characterization data enable unique materials to be identified, provide knowledge of where unique landraces or primitive cultivars originated so that they can be conserved in the right areas in relation to grow-outs, and facilitate decisions on what should justifiably be conserved by whom.

Making the collections more representative means analyzing patterns of ecogeographic differentiation, identifying related species that comprise crop genepools, ensuring that 90% of the effort is not being targeted to save only 10% of the known diversity, and planning for additional exploration and collecting to amplify collections while avoiding duplication of effort. Genetic erosion will not wait for approval of pending international agreements or networking arrangements.

Action needs to be spurred by scientists, as it was in the past, because comparatively little is known of genepool representation or distribution in many cases, and only scientists can give the best-informed opinion. We believe that emergency action plans should be formulated for major commodities, to be completed in a five-year period. Each should have elements of collecting, integrated database development, and secure storage and description. They would address filling gaps identified in the early 1980s (Williams, 1984) and some that still remain today (Williams, 1991).

Such action plans could take into account the numbers of samples estimated to be required by the World Resources Institute (WRI, 1992) for crop genepools, forest species, medicinal plants, ecosystem rehabilitation, and traditional underexploited plants. Many existing institutional operations could be "signed up" for this endeavor with some re-allocation of funding. At least by the end of the decade of biodiversity these action plans would have accomplished much for true conservation collections despite a degree of guesswork.

They would be seen as insurance policies and would properly complement other activities such as in situ conservation of ecosystems. At the same time, a major gap could be addressed: how to integrate ex situ activities with in situ programs. Leadership is desperately needed to provide diverse guidelines for genetic management of populations in situ and cross-indexing databases of protected area inventories with ex situ integrated databases. For example, as many as 200 crop species originated in tropical and subtropical forests, and many still have wild populations there (Smith et al., 1992), but no detailed databases provide information for either conservationists or crop enhancers. The availability of emergency action plans would make it easier for national programs to identify their own roles and for the strategically-determined national plan of action (Cohen et al., 1991) to be justified in terms of the inter-dependency of nations on plant resources.

54–3 VALUING INVESTMENTS IN GENETIC RESOURCES

Conservation of resources is a multi-institutional, multi-component effort. Funds required to effectively and efficiently preserve genetic resources for future generations have not been properly estimated nor provided for required conservation efforts, as exemplified by the U.S. National Plant Germplasm System (NAS, 1991).

What are potential sources of funding for conservation of genebank-based genetic resources? Tax-based revenues supporting conservation represent a major portion of available funds. However, general deficiencies in this sector, coupled with a lack of long-term investment strategies, is a recognized problem (Mares, 1986). In the USA, approximately 2% of the national budget ($14 billion in 1983) was allocated to domestic natural resources and environment programs. Because of weak economies in many developing countries, an equivalent expenditure is virtually impossible. Contributions by the

USA in 1989 for conservation of diversity abroad were $62.9 million, yet countries receiving larger portions of these funds still lacked resources to curb the loss of biodiversity (Abramovitz, 1991).

Greater support must be obtained for conservation-level investments to increase returns derived through use of genetic resources. Without such investment, and recognition of the value of this investment, resources will remain untapped, as if sealed in a vault or be used without recognition, credit, or documentation provided to the relevant conservation program, or, be exploited in a nonsustainable manner.

In effect, ex situ programs may compete with one another for clients as users discover which program is most able to provide reliable services. Many user groups, both public and private, are in need of high-quality, well-characterized samples of conserved accessions. Thus, a potential source of income is being missed because genebanks are often not able to effectively conserve, characterize, and ensure viability of accessions. Over time, users will pay careful attention to the quality of service provided by each conservation program. Certainly, there can be little claim to fees for dead or inviable seed samples or for accessions that cannot be found due to inaccurate inventories, and that are infested with pathogens, and are poorly characterized. It is also a concern when no forethought is given to the potential worth of such material by the host country institution.

On the contrary, when services, accessions, and data provided by the genebank are determined to be of good quality, this should be acknowledged as a "value-added" feature following the original acquisition, rather than being taken for granted. This will be true whether the sample was acquired by collection, exchange, or is indigenous or exotic. Added value comes from attributes applied to accessions incorporated into genebanks. Such value is desperately needed within national and international ex situ and in situ collections of plant germplasm. However, to what extent can these activities be undertaken when financial resources are limited to the most basic aspects of conservation or preservation? Managers of ex situ centers of diversity must be able to effectively interact with legal, scientific, and commercial partners to help enhance the value of their collections. For example, agreements may be developed to ascertain the range of molecular diversity for certain traits among accessions of a particular species. The number of viable, unique samples in a collection increases the range of diversity that could be sampled. Financial arrangements would be needed to supply the samples, develop the molecular analysis, and finally, to determine how results and the most promising germplasm would be handled.

54–4 HUMAN RESOURCE DEVELOPMENT AND RESOURCE CONSERVATION

Development and expansion of crop genetic resource programs over the past decade have demonstrated the need for relevant training. Well-functioning genebanks require strong programs that link variation stored in conservation collections with crop improvement (Goodman, 1990). Genebanks in developing countries can more effectively contribute to improving agronomic productivity when supported by concurrent increases in plant breeding and in the development of seed industries to produce elite seed.

When training for plant genetic resources was initiated in the United Kingdom, with the moral support of FAO in 1969 and strong support from IBPGR after 1975, this provided the emerging genebank system with scientists trained in all the multi-disciplinary aspects of genetic resources. This was supplemented with numerous short courses organized by IBPGR, other IARCs, and some national programs. However, the volume of people trained has fallen short of the needs.

A review of the U.S. National Plant Germplasm System (NAS, 1991) suggested the need to develop a significant international extension to its existing domestic mandate. Also more "hands-on" internships at Universities and Centers are needed (Cohen et al., 1991).

As genetic resource programs expand their scientific and technical base, and define their relation with other conservation efforts, new needs in conservation management emerge. To address these needs and to form more integrated conservation efforts, germplasm practitioners must apply disciplines as diverse as population genetics, demography, field collecting, seed storage, propagation, tissue culture, and various maintenance strategies. New educational opportunities, such as the Summer Institute for Genetic Resource Conservation, provide key opportunities to explore these diverse topics and acquaint germplasm professionals with their inter-relationships (McGuire, 1991).

The needs of both the genetic-resources workers and the user community are pertinent issues. First, the requirements of managers of genetic resources programs are changing. Whereas 20 yr ago, their work was largely for conservation as a service function to breeding—if it existed—they now need to interact with nature conservation for conservation of biodiversity, with forestry genetic resources requirements, and others. Strategic national planning is required as well linking global activities on any specific crop genepool (Cohen et al., 1991).

Second, the number of plant breeding graduate students is declining in parallel with the upsurge of interest in biotechnology. Aside from the prebreeding or enhancement that can utilize genes in primitive and wild materials, the more traditional breeding requires a 5- to 15-yr development period. Broader genetic enhancement programs will maximize and justify the use of germplasm collections. Once implemented in a country, the use of modern crop cultivars can only be sustained through a well-planned plant breeding program and clear strategy by the genebank manager and breeders. The need for sustainability should not detract from this; there will be no return to peasant agriculture except in marginal areas where it is possibly more environmentally sound. Plant breeding aims might move somewhat from total use of monocultures to more consideration of cultivar mixtures and intercropping systems. This will require regional cooperation, and genebank managers must develop new skills to avoid the problems of many past regional programs. The following educational programs will be required to meet their needs:

1. Training of genebank personnel to strategically manage collections.
2. Educating conservation biologists to recognize the needs of their colleagues dealing with genetic resources, and for a certain number to be fully trained in curating and managing genetic reserves as parts of the broader ecosystem conservation and in conserving threatened species ex situ.
3. Preparing biodiversity scientists to recognize the urgent applied aspects so that crop, forest or forage genepools can be described in terms of patterns of variation using modern molecular and biochemical methods, and for research to be strategic and applied rather than basic.
4. Training managers in research planning, monitoring, and development of fully collaborative programs to maximize cost-effectiveness and efficiency. Curators must become much more pro-active to address these needs (Williams, 1985); they should collectively determine how worldwide cooperation and collaboration in germplasm availability and use develop. There are important messages here for the Consultative Group on International Agricultural Research (CGIAR) as it moves to policies in this area and networking on specific crop germplasm through IBPGR.

The training needs above are not being addressed fully, and there does not appear to be a clear policy agreed upon by all the international organizations involved. The job of resource manager begins where that of a policy maker leaves off (Orians et al., 1990) but synergies between the two are necessary to make technology effective, to cope with uncertainty, and to choose and manage existing technologies. Training in this area is still virtually non-existent.

54–5 FACILITATING MOVEMENT AND AVAILABILITY OF GENETIC RESOURCES

The centers of diversity concept has been overplayed in debates on plant genetic resources. Although these were valuable for highlighting collecting needs in the past, there is no longer justification for overemphasizing them. The historical diffusion of crops was instrumental in their diversification, providing the foundation for crop development. In the case of wheat (*Triticum aestivum* L.), early cultivars from Canada were derived from cultivars from Poland, India, Russia, and England (Knott, 1967) and not directly from materials in the center of origin. Now the genepool of several genera of the Triticeae, a tribe of the grass family, is of value and species are distributed over vast territories of the globe.

Hence, it is difficult to understand why the rhetoric developed for and by developing countries rich in germplasm to perceive the indigenous plant genetic material as a *national* biological treasure, except where high value industrial crops had become economically strategic (Chang, 1992). The interdependence of global genetic resource conservation centers and the plant breeding community attest to the fact that area of origin has far less consequence than what and how the seed is used, how much is available, its viability, and national capabilities for storage and use (Cohen & Bertram, 1989). Modern plant breeding programs are themselves becoming centers of diversity as they continually merge elite lines that are geographically and genetically diverse (Baezinger & Peterson, 1992). Rarely is any territory, defined by national boundaries, self-sufficient in germplasm for continued crop enhancement.

The key to overcoming the problems of an ever-increasing population, continued problems of rural poverty, and the fact that breeding new cultivars takes considerable time, will be the ongoing availability of genetic resources to sustain crop enhancement. Debates on sovereignty must not delay such efforts.

Other factors also are important. They relate to how well genetic resource collections are managed in terms of sample quality, quantity, security in conservation, uniqueness, inventory status. Limitations in any one of these areas, especially in collections involving international custodial responsibilities, will affect the ready availability of material for distribution.

It is not simply a question of mobilizing more funding. There is a major moral responsibility to ensure that the collections are "in order" and not littered with small samples in need of multiplication, and that they are adequately evaluated and characterized. The constraints are known (Williams, 1989; Goodman, 1990) and there are some hopeful programs in place to remove restrictions on some crop samples. A program initiated by Agency for International Development (A.I.D.) and implemented by Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and 13 national programs will regenerate essential accessions of Latin American and Caribbean maize. Duplicate samples were placed in the National Seed Storage Laboratory in Ft. Collins, CO. The program will regenerate approximately 3,700 of the most critical maize accessions (Cohen, 1991).

In many cases, large-scale evaluations are limited by resources. There is, therefore, clear responsibility to prioritize and transfer information among genebanks, and to address specific short- and medium-term constraints to production. The latter has been stressed by Srivastava and Damania (1990) in relation to wheat and by Frankel and Brown (1984) as a matter of principle. Unfortunately, however, it has not been adequately emphasized in relation to global food needs of the next 20 yr when institutional structures and implementation mechanisms become the main focus of discussion (Keystone, 1991; von Hintum et al., 1991).

Borlaug (1989) summarized the needs for increased production, economic policies to encourage adoption of new technologies, and aggressive enthusiastic production campaigns, but warned that the attitude of scientists, political leaders, and the general public will be decisive in determining whether we reach the food production target that will sustain our civilization.

Consideration of essential food supplies clearly must be the over-riding concern in setting priorities for further field collecting of germplasm and evaluation of all conserved materials to promote more rapid use. In part this conflicts with perceived needs to conserve large segments of useful diversity because of threats of loss. It is impossible to conserve everything; existing collections are straining the available scientific, managerial, and financial resources. The priorities should address the global needs as well as demonstrated regional needs for a limited range of commodities. It is justifiable that more emphasis be placed on landraces of major crop species than those of the minor crops and that collections of the former are larger. For these minor crops and for species of yet unknown potential, insurance through nature conservation will probably be adequate with specific segments of the genepools under threat conserved in situ or ex situ depending on the degree to which they are expected to survive in for an extended period without undue intervention. Large ex situ germplasm collections, which are costly to maintain, are only needed to ensure ready availability for use and for preservation of threatened species.

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