A brief history of plant germplasm collecting

1

Co-sponsors

Plant genetic diversity is the key component of any agricultural production system – indeed, of any ecosystem. Without it, no natural, evolutionary adjustment of the system (agricultural or natural) to changing environmental and biotic conditions would be possible. Farmers would not be able to spread the risk of crop failure or experiment with and refine crop varieties to suit their tastes and changing needs. Agricultural science and forestry would not have the basic raw materials for their introduction, domestication and improvement programmes. For development to be sustainable, conservation and use of genetic diversity must be at its core. Because the world is dynamic, this need for diversity is continuous. It is also increasing, because the number of people that must be fed, kept warm, housed and cured is increasing.

For thousands of years, wild habitats and farmers with their fields, orchards and home gardens have been sufficient to ensure the conservation, within the framework of change dictated by natural and artificial selection, of the vital natural resource that is the genetic diversity of plants. However, these systems have recently come under increasing pressure from demographic, socioeconomic and technological change. In some parts of the world, they have been under such pressure for hundreds of years. The results have been habitat fragmentation and even destruction, the abandonment of traditional agricultural and natural resources management practices and the replacement of farmers' landraces by modern cultivars. Species have always become extinct and landraces gone out of fashion, of course, but the current pace is unprecedented, and variety is being replaced by uniformity, rather than more, different variety. The result is a loss of genetic material, an irreversible erosion of genetic diversity. Active measures, both institutional and grass-roots, to ensure the conservation of plant genetic resources have thus taken on an increasing urgency of late.

Two strategies have been followed, their complementarity now recognized by the *Convention on Biological Diversity* (Articles 8 and 9), *Agenda 21* (Chapters 14 and 15) and the *Global Biodiversity Strategy* (WRI *et al.*, 1992). One approach involves the fostering and protection of the systems in which wild species have evolved, and crops have been developed. Biosphere Reserves, national parks and other kinds of protected areas, sustainably managed forests and the efforts of (in particular, though not exclusively) non-governmental organizations (NGOs) in on-farm and community-level crop conservation are examples of the application of such an *in situ* strategy. However, it is also possible for the conservation process to take another course. Propagules and other plant parts may be collected from the field and transferred to a suitable form of *ex situ* storage facility. Orthodox seeds and pollen may be maintained in cold storage of different types, whole plants and perennating organs in a field collection, arboretum or botanic garden and *in vitro* samples in the tissue culture laboratory under slow growth conditions or cryopreservation. In the gene bank and botanic garden, germplasm is both conserved and made available for study and use. Different species and situations will require different mixes of *in situ* and *ex situ* approaches.

Collecting germplasm – the first step in *ex situ* conservation and clearly a prerequisite for use of the material – is not as easy as it may sound. It is not simply a matter of being at the right place at the right time (though even this can on occasion be difficult enough) and putting a few seeds in a bag. Target species must be found and correctly identified. A decision must be taken as to what plant part or parts to collect. An attempt must be made to capture maximum diversity for the amount of material collected and resources expended. The material must be kept viable under often difficult field conditions. The germplasm must be carefully documented if it is to be useful to the eventual user.

Even deciding what plants to collect can be difficult. The genetic diversity of a given species extends beyond its taxonomic boundaries. The gene pool of a crop includes not only traditional local forms (landraces) but also wild and weedy relatives. The entire gene pool forms the basic unit of conservation and must be the ultimate target of genetic resources collecting. Crop relatives are not the end of the story, however. There are well over a quarter of a million plant species on this planet, and only a small proportion falls in the gene pools of current crops. Thousands of species are exploited by local communities and their livestock but are not domesticated. Then there are forest trees, the thousands of species used in traditional medicine and the vast ranks of ornamentals. Many plants are important in land management and habitat restoration or rehabilitation. Which other species have the potential to prove significant in the future as sources of food, medicines, energy and industrial products? What are the keystone species of ecosystems? Which are the most threatened?

Farmers have always recognized the value of exotic plants and novel crops and varieties. In the Andes, they have gathered for centuries at regional fairs to exchange planting material and learn from each other. In eastern Sierra Leone, women expect to take seeds and plants from each other's farms to meet immediate consumption needs. They also do so to obtain desired planting material, which may also be given as gifts during visits to family members in distant villages and towns (Leach, 1991). In some parts of India, it is customary for a bride to bring a gift of rice seeds grown by her family to her new husband's home. The state has also contributed to the process of germplasm collecting and transfer. Almost a thousand years ago, Emperor Chen-Tsung introduced Champa varieties of rice from Vietnam to China's Yangtze Delta, perhaps the first large-scale germplasm introduction. Plant collecting has in fact been one of the most powerful stimuli to exploration down the ages. Some 3500 years ago, Queen Hatshetput of Egypt dispatched a collecting expedition to Punt: the bas reliefs at the Deir al-Bahar temple show live frankincense trees, precious for their perfumed gum, being carried along in a procession. Though germplasm was not the kind of riches they primarily had in mind, the Iberian colonists engaged in plant collecting 500 years ago in the New World, unwittingly starting a major programme of germplasm exchange with the Old World which is still continuing and which is helping to feed both. Three centuries later, Captain Bligh was leading a germplasm collecting expedition which included two horticulturalists from the Royal Botanic Gardens, Kew, when the famous mutiny occurred. The *Bounty* was transporting breadfruit seedlings from Tahiti to the West Indies. The idea had been Sir Joseph Banks', famous for botanical collecting in Canada, New Zealand and points between.

In modern times, the institutional roots of the kind of germplasm collecting exemplified by the *Bounty*'s mission can be traced back to the hospital gardens of the Muslim world and the herb and medicinal gardens of the monasteries of medieval Europe, the precursors of the 'physic' gardens established in Renaissance Italy in connection with the first universities. The development of botanic gardens from the largely medicinal gardens of the 16th and 17th centuries was largely determined by a desire to increase the variety of collections. To this end, plant collectors were sent out to various parts of the world to bring back species new to cultivation, initially to the Near East, later to the Americas, southern Africa, Australia and the Far East. Orangeries and the first glasshouses greatly expanded the range of plants that could be cultivated. As the exploration of the tropics by the emerging colonial powers continued, the first botanic gardens outside Europe were created, such as those at the Cape of Good Hope (South Africa), Pamplemousses (Mauritius), Buitenzorg (now Bogor, Indonesia), Calcutta (India) and Bath (Jamaica). These served as introduction and acclimatization centres for a wide range of crops, fruits, spices and ornamentals (Smith, 1986; Heywood, 1990).

The largest network of botanic gardens was that created in the former British colonies under the aegis of the Royal Botanic Gardens at Kew. These were responsible for the movement of vast amounts of germplasm around the world. The flow was not only North–South, but also South–South, as material introduced through a botanic garden in one country was sent for trial in other parts of the world with a suitable climate. European botanic gardens also served as staging posts. The Royal Botanic Garden at Edinburgh, for example, received seedlings of coffee from Java via the Hortus Botanicus in Amsterdam and sent some on to Nyasaland (today Malawi). In the opposite direction, Leiden Botanic Garden served as an intermediary for the transfer of the vanilla orchid from South America to Java. Kew received 70,000 rubber seeds from the Brazilian Amazon in 1876, of which 2397 germinated; almost 2000 seedlings were then sent on to the botanic garden at Heneratgoda (Sri Lanka), which had been specially created to receive them, and smaller numbers to Calcutta and Singapore. The scale of operations was often vast. Between 1873 and 1876, almost 3.5 million seedlings of chinchona, a species newly introduced through Kew, were made available to local planters by the botanic garden at Hagkala (Sri Lanka).

Another important mechanism for collecting and distributing germplasm was the seed exchange system that was formalized in the 18th century as the *Index Seminum*. Through this mechanism, seeds and other propagules are offered for free exchange between botanic gardens throughout the world. Today, some 800 botanic gardens regularly issue such seed lists, which are analogous to the accession catalogues of gene banks. Prior to this, the holdings of botanic gardens were frequently listed in specially published catalogues, which often contain invaluable information about the first introduction of plants into cultivation.

A major contribution of botanic gardens to plant introduction has been in the field of ornamental plants. An important figure was George Forrest, who was sent by the Royal Botanic Garden, Edinburgh, to western China and Bhutan at the beginning of this century. Among his introductions were many *Rhododendron* and *Primula* species, for which Edinburgh is now famous, and *Meconopsis* and *Lilium* species. Plant collecting expeditions from Edinburgh to China continue to the present day, in collaboration with local botanists and botanic gardens.

The number of species introduced into cultivation by botanic gardens probably runs to 80,000 or more. Many of these are represented by only small samples, sometimes single individuals, of limited value as genetic resources. However, in the last decade many botanic gardens have adopted more specialized sampling procedures, and over 120 maintain seed banks. These range from fully equipped facilities like that of the Royal Botanic Gardens, Kew at Wakehurst Place to simple collections in vials in deep freezes. Many more gardens maintain significant conservation collections of growing plants.

Botanic gardens have not, however, been the only modern institutions instigating scientific germplasm collecting, or the only recipients and guardians of the material. The private sector has been active, in the form of commercial nurseries, seed companies, gardening societies and the like. Nowadays, the field increasingly includes NGOs and other local grass-roots organizations. Government bodies dealing with agriculture and forestry took their cue from the early botanic gardens. In the USA, for example, the Office of Foreign Seed and Plant Introduction of the Department of Agriculture sponsored many expeditions in the early 1900s. The Act which established the Department under President Lincoln set out its tasks as 'to collect . . . new and valuable seeds and plants; to test, by cultivation, the value of such of them as may require such tests; to propagate such as may be worthy of propagation, and to distribute them among agriculturists' (Berg *et al.*, 1991). Among its outstanding collectors were David Fairchild, Frank Meyers, Joseph F. Rock and Wilson Popenoe, but even diplomats and military personnel serving abroad contributed. They continued a tradition of plant introduction into the USA that goes back to the first settlers and to the 'botanist-kings' of the early years of the republic, people like Benjamin Franklin, George Washington and Thomas Jefferson, who knew all about the activities of botanic gardens like Kew.

Initially, the material obtained by the Office of Foreign Seed and Plant Introduction was maintained in living collections or as seeds stored at ambient temperature and grown out every year. In the late 1940s, as it became clear that only a very small percentage of the tens of thousands of accessions collected in the previous half-century could be accounted for in living collections, four regional centres for storing seeds under medium-term conditions (i.e. at about 0°C) were established in the USA. These were joined in 1958 by the National Seed Storage Laboratory, which was later upgraded for long-term storage (i.e. at about −15°C).

Perhaps the most significant of the national germplasm institutions of the early part of this century was the All-Union Institute of Plant Introduction in St Petersburg, Russia. Established in 1890, in the 1920s it began to house the extensive worldwide collections being amassed by Nikolai I. Vavilov and his colleagues. It was later renamed the N.I. Vavilov All-Union Scientific Research Institute of Plant Industry (VIR) in honour of his achievement. Vavilov, in many ways the pioneer of scientific, systematic germplasm collecting, gathered some 50,000 samples of crop plants in over 50 countries in the 1920s and 1930s. His work set a pattern, as can be seen by what happened in potato collecting in Central and South America. In the wake of Soviet missions in 1925–27 came American, German, Swedish and British collectors in the 1930s, including Jack Hawkes, later one of the founders of the worldwide movement to conserve plant genetic resources. This was followed by collecting by the Latin American countries themselves, culminating in the life-work of such legendary plant explorers as Carlos Ochoa. The Centro Internacional de la Papa (CIP), one of the centres of the Consultative Group on International Agricultural Research (CGIAR), is the heir to this international collecting programme.

The Vavilov Institute acquired long-term seed storage capability in the 1970s. Smaller national gene banks were also established around that time in various European countries, Australia, Canada and Japan, in some cases as the culmination of national collecting efforts going back almost a century. The year 1990, for example, marked the twentieth anniversary of the establishment of the gene bank at Braunschweig in Germany but also the hundredth anniversary of the International Agricultural and Forestry Congress, held in Vienna, at which Emanuel Ritter von Proskowetz and Franz Schindler reported on the importance of landraces in agriculture. The former's collection of Moravian barley landraces is still justly famous.

In the 1960s, the realization began to grow that developing countries (and, indeed, local communities) must be integrated to a much greater extent into a global plant genetic resources system. That was where crop genetic diversity was not only most abundant, but also most at risk, as the Green Revolution got into its stride. The Food and Agriculture Organization of the United Nations (FAO) had actually initiated international discussions as far back as 1947 and introduced the first international newsletter on crop genetic resources in 1957, the precursor of today's *Plant Genetic Resources Newsletter.* Following a Technical Meeting which its Plant Production and Protection Division convened in 1961, a Panel of Experts on Crop Germplasm Exploration and Introduction was set up in 1965, with Sir Otto Frankel as chair. A similar panel on forestry was established in 1968, followed by an Expert Consultation on Forest Genetic Resources. In several meetings held over nine years, the crop experts set priorities for exploration, drafted proposals for an international network of genetic resources centres and developed guidelines for international cooperation in seed conservation. The International Biological Programme (IBP) was closely involved in this process. One of the more important outcomes was Frankel's *FAO/ IBP Survey of Crop Genetic Resources in their Centres of Origin,* published in 1973. FAO's Crop Ecology and Genetic Resources Unit started work in 1968, including wide-ranging germplasm collecting, for example by Erna Bennett, herself the author of pioneering papers. As awareness increased of the importance of plant genetic diversity in sustainable development, and of the threat it was facing, systematic worldwide collecting for long-term conservation began in earnest.

FAO Technical Conferences on plant genetic resources were held in 1967, 1973 and 1981. In addition to Sir Otto Frankel and Erna Bennett, R.O. Whyte, Jack Harlan, T.T. Chang, Jack Hawkes and others played an important part in organizing these early meetings. In 1972, the UN Conference on the Human Environment, held in Stockholm, gave FAO responsibility for the establishment of an International Genetic Resources Programme, in addition to leading to the setting up of the United Nations Environmental Programme (UNEP). FAO then submitted to the CGIAR a proposal which eventually led, in 1974, to the establishment of the International Board for Plant Genetic Resources

(IBPGR) by the CGIAR. Placed within the institutional framework of FAO, the mandate of IBPGR was to help coordinate plant genetic resources activities worldwide.

Germplasm collecting was one of IBPGR's main activities in the early years, always in collaboration with the national plant genetic resources programmes that it was at the same time helping to strengthen and in some cases start. Collaboration with international agricultural research centres (IARCs) both inside and outside the CGIAR was also strong. Many IARCs have germplasm collecting and conservation programmes of long standing: for example, Carlos Ochoa worked at CIP from 1971 and T.T. Chang at the International Rice Research Institute (IRRI). The initial stress at IBPGR, as at the commodity IARCs, was on the broad-scale, worldwide collecting of germplasm of the major food crops, which were thought to be most threatened by genetic erosion. More recently, work on such staples has concentrated on gap-filling and collecting for special purposes. Since the mid-1980s, increasing emphasis has been placed by the plant genetic resources community, including IBPGR, on forages, multipurpose trees, wild crop relatives and less well-known crops. Forestry species have recently been added to IBPGR's (and the CGIAR's) mandate. By the beginning of the 1990s, IBPGR had sponsored some 650 missions in about 130 countries, for a total of almost 200,000 samples collected. In 1974 there were ten long-term seed storage facilities in the world, nine in developed countries. By 1990 there were 89 in developed countries and 39 in developing countries, storing some three and a half million accessions collected by national, regional and international organizations, mostly during the previous 20 years or so.

In late 1991 an international agreement was signed by five governments establishing the International Plant Genetic Resources Institute (IPGRI) as the independent successor to IBPGR. IPGRI, in close partnership with FAO and other international organizations, continues to be actively involved in germplasm collecting and seeks above all to work with and strengthen the collecting and other conservation activities of national plant genetic resources systems in developing countries. These systems can be anything from a single institute with the facilities for *ex situ* conservation to a committee representing a national network of crop-specific agricultural research institutes, university departments and botanic gardens. The private sector may also be involved. The extent of coordination in such a system varies widely from country to country. The priorities of a national programme will depend on needs, on national research and development capacity and on the diversity of germplasm within the country, but collecting will usually feature to at least some extent. National plant genetic resources systems are the building-blocks of the global conservation effort. Increasingly, they include NGOs and grass-roots organizations, an 'informal' sector to set besides the 'formal', institutional sector represented by gene banks, botanic gardens and arboreta.

National programmes and their collecting activities have been supported by both bilateral and multilateral development agencies. They also collaborate among themselves in collecting. An example is the long-standing collaboration between the gene bank of the Institute of Plant Genetics and Crop Plant Research, at Gatersleben in Germany, and the national programmes of Cuba and other countries. In some cases, collaboration among the national programmes of developing countries is supported, technically and/or financially, by regional organizations. Examples are the Regional Plant Genetic Resources Centre of the Southern Africa Development Community (SADC) in Lusaka, Zambia, and the Centro Agronómico Tropical de Investigaçión y Enseñanza (CATIE) at Turrialba, Costa Rica.

An international framework for these disparate activities is provided by the Resolution of the 1983 FAO Conference, which established the Commission on Plant Genetic Resources as a global forum for plant genetic resources debate. The Commission, whose Secretariat is provided by the Plant Production and Protection Division of FAO, has met five times since 1983 and now numbers 123 member countries. Its role in monitoring the implementation of the principles of the International Undertaking on Plant Genetic Resources and in drawing up an International Code of Conduct for Plant Germplasm Collecting and Transfer is discussed in Chapter 2.

There is thus nothing new about germplasm collecting. It has been done, and continues to be done, by all kinds of different people – conservationists, ecologists, botanists, foresters, breeders, geneticists, extension officers, development workers, local communities themselves – who have different immediate interests and concerns. They have also had to deal with a huge range of plants – wild and cultivated, annual and perennial, woody and herbaceous, outbreeding and inbreeding, seed-producing and vegetatively propagated. Until relatively recently, they have not had much in the way of guidelines to follow. A turning-point was the publication in 1970 of *Genetic Resources in Plants – Their Exploration and Conservation*, edited by Sir Otto Frankel and Erna Bennett. This volume grew out of the 1967 FAO Technical Conference and included several papers giving valuable practical advice to the germplasm collector. Another, equally important work emerged after the 1973 meeting: *Crop Genetic Resources for Today and Tomorrow*, edited by Sir Otto Frankel and Jack Hawkes (1975). In 1972 a *Manual for Field Collectors of Rice* (Chang *et al.*, 1972) was published, the fruit of a decade of experience in rice collecting by IRRI, but as the title implies its scope is limited. The same is also true of the Centro International de Agricultura Tropical (CIAT)'s *Handbook for the Collection, Preservation and Characterization of Tropical Forage Germplasm Resources* (Mott and Jiménez, 1979).

From the mid-1970s, there was a rapid increase in the number of publications on the theoretical and practical aspects of germplasm collecting, particularly as regards crops. Much of this information was synthesized by Prof. Jack Hawkes in his *Crop Genetic Resources Field Collection Manual* (Hawkes, 1980), co-sponsored by IBPGR and the European Association for Research on Plant Breeding (EUCARPIA). More specialized guides followed. For example, FAO produced publications on collecting forestry species (e.g. Ffolliott and Thames, 1983; FAO, 1985). Marchenay's (1986; 1987) 'Guide pratique' and 'Guide méthodologique' apply the methods refined over the previous 15 years or so to the specific problem of collecting traditional crop varieties in France. Kenya Energy Non-Governmental Organization's (KENGO) *How to Collect, Handle and Store Seeds* (Mboye and Kiambi, n.d.) is an example of a developing country NGO publication in the field, with the emphasis on 'easily digestible and synthesized technical information'.

Following a series of Conservation Conferences held at Kew, beginning in 1975 with *The Function of Living Plant Collections in Conservation and Conservation-Oriented Research and Public Education* (Simmons *et al.*, 1976), the botanic garden sector began to play an increasingly important role in the collecting and conservation of germplasm, especially of wild species, including medicinal plants and ornamentals. The *Botanic Gardens Conservation Strategy*, published in 1989 by the World Wide Fund for Nature (WWF), the World Conservation Union (IUCN) and the Botanic Gardens Conservation Secretariat (today Botanic Gardens Conservation International, BGCI), focused attention on the priorities for germplasm conservation by botanic gardens. BGCI has also produced a set of *Guidelines for the* Ex Situ *Conservation of Germplasm by Botanic Gardens* (BGCI, 1993). The Centre for Plant Conservation (CPC) at St Louis has published 'Genetic sampling guidelines for conservation collections of endangered plants' (CPC, 1991). Various workshops and symposia on genetic resources conservation, plant introduction by botanic gardens and related topics have been published (e.g., He *et al.* 1990; Hernández-Bermejo *et al.*, 1991; Hamann, 1992). The *Guidelines on the Conservation of Medicinal Plants* (WHO *et al.*, 1993) include sections on collecting and conservation.

As the 1990s began, it became evident, however, that there was no single publication available which could be consulted by the prospective collector of plant germplasm for generic as well as specific, and theoretical as well as practical, information. Some topics had not previously been dealt with fully, other fields had advanced very rapidly. It was to fill this gap that IBPGR, FAO, UNEP and IUCN agreed to cooperate in the publication of the present volume of *Technical Guidelines* for plant germplasm collectors, aimed both at the newcomer to the field and the experienced worker faced with new technical challenges.

A major impetus to this effort was the UN Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992 and the spiritual successor of the 1972 Stockholm Conference, which in different ways led to the establishment of both UNEP and IBPGR. The UNCED Conference adopted *Agenda 21*, a global environment and development programme which recognizes the crucial importance of plant genetic resources conservation – both *in situ* and *ex situ* – to future development prospects. The *Convention on Biological Diversity* was also opened for signature at the Conference, and came into effect in late 1993. This will have a profound impact on plant germplasm collecting policies and programmes. Article 9 of the *Convention* calls upon countries to 'adopt measures for the *ex situ* conservation of components of biological diversity, preferably in the country of origin of such components'. One of these measures must of course be a technically sound germplasm collecting programme, and it is hoped that this book will provide the basis on which such a programme can be constructed and run. Much remains to be done. This was underlined as recently as 1991, when the Final Consensus Report of the Keystone International Dialogue Series on Plant Genetic Resources noted that: 'The inadequacy of most current collections is widely recognized. Even in major crops, there are important areas of diversity that remain to be sampled, and some areas where past sampling was inadequate or faulty may need to be revisited.'

References

Berg, T., Å. Bjornstad, C. Fowler and T. Skroppa (1991) *Technology Options and the Gene Struggle*. NORAGRIC, Aas.

BGCI (1993) *Guidelines for the* Ex Situ *Conservation of Germplasm by Botanic Gardens*. Botanic Gardens Conservation International and Cabildo Insular de Gran Canaria, Las Palmas de Gran Canaria.

Chang, T.T., S.D. Sharma, C. Roy Adair and A.T. Perez (1972) *Manual for Field Collectors of Rice*. IRRI, Los Baños.

CPC (1991) Genetic sampling guidelines for conservation collections of endangered plants. In: Falk, D.A. and K.E. Holsinger (eds) *Genetics and Conservation of Rare Plants*. pp. 209–238. Oxford University Press, New York.

FAO (1985) *A Guide to Forest Seed Handling (With Special Reference to the Tropics)*. FAO Forestry Paper 20/2, compiled by R.L. Willan. FAO, Rome.

Ffolliott, P.F. and J.L. Thames (1983) *Collection, Handling, Storage and Pretreatment of Prosopis Seeds in Latin America*. FAO, Rome.

Frankel, O.H. and E. Bennett (eds) (1970) *Genetic Resources in Plants – their Exploration and Conservation*. Blackwell Scientific Publications, Oxford.

Frankel, O.H. and J.G. Hawkes (eds) (1975) *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, Cambridge.

Hamann, O. (ed.) (1992) *Ex situ* conservation in botanical gardens. *Opera Botanica* 113.

Hawkes, J.G. (1980) *Crop Genetic Resources Field Collection Manual*. IBPGR and EUCARPIA, Rome.

He, Shan-an, V.H. Heywood and P.S. Ashton (eds) (1990) *Proceedings of the International Symposium on Botanic Gardens*. Jiangsu Science and Technology Publishing House, Nanjing.

Hernández-Bermejo, E., M. Clemente and V.H. Heywood (eds) (1991) *Conservation Techniques in Botanic Gardens*. Koeltz Scientific Books, Koenigstein.

Heywood, V.H. (1990) Botanic gardens and the conservation of plant resources. *Impact of Science on Society* 158:121–132

Leach, M. (1991) Women's vegetable production in eastern Sierra Leone. In: Camman, L. (ed.) *Peasant Household Systems*. Proceedings of an International Workshop. 3-5 April 1990. Feldafing. pp. 186-208. Deutsche Siftung für Internationale Entwicklung (DSE), Feldafing.

Marchenay, P. (1986) *Prospection et Collecte des Variétés Locales de Plantes Cultivées*. Groupe de Recherche et de Développement sur le Patrimonie Génétique et Végétal de la Région Provence-Alpes-Côte d'Azure (PAGE-PACA), Hyères.

Marchenay, P. (1987) *A la Recherche des Variétés Locales de Plantes Cultivées*. Groupe de Recherche et de Développement sur le Patrimonie Génétique et Végétal de la Région Provence-Alpes-Côte d'Azure (PAGE-PACA), Hyères.

Mboye, A. and K. Kiambi (n.d.) *How to Collect, Handle and Store Seeds*. KENGO, Nairobi.

Mott, G.O. and A. Jiménez (eds) (1979) *Handbook for the Collection, Preservation and Characterization of Tropical Forage Germplasm Resources*. CIAT, Cali.

Simmons, J.B., R.I. Beyer, P.E. Brandham, G.Ll. Lucas and V.T.H. Parry (eds) (1976) *Conservation of Threatened Plants*. Plenum Press, New York.

Smith, N.J.H. (1986) *Botanic Gardens and Germplasm Conservation*. Harold L. Lyon Arboretum, University of Hawaii Press, Honolulu.

WHO, IUCN and WWF (1993) *Guidelines on the Conservation of Medicinal Plants*. IUCN, Gland.

WRI, IUCN and UNEP (1992) *Global Biodiversity Strategy. Guidelines for Action to Save, Study and Use Earth's Biotic Wealth Sustainably*. WRI, IUCN and UNEP, Washington DC.