An introduction to plant germplasm exploration and collecting: planning, methods and procedures, follow-up

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This chapter deals mainly with the planning that plant germplasm collecting trips require, but also with some general considerations regarding their conduct and with some important follow-up activities. It acts as an introduction to the rest of this volume of *Technical Guidelines*, pointing to its various other chapters along the way, which provide more information on specific topics. This has been planned as a reference work. It cannot hope to provide all the information that will be required by collectors, but will at least point to the best sources of information. It seeks to set a common standard that can be followed by all those involved in germplasm collecting to ensure that the material they collect is viable, representative and adequately documented when it comes to be used. The volume is divided into four main parts. The first, Before Setting Out, deals in detail with the scientific and logistical planning of germplasm collecting missions and programmes. The second, In the Field, is concerned with specific collecting techniques and procedures. This is followed by Back at Base. The final part contains Case-Studies chosen to represent a range of species and types of collecting missions.

The importance of preparatory studies has been well summarized by Bunting and Kuckuck (1970):

> The ecological appreciation needed in plant explorations must be based on broad studies of the region as a whole, completed as far as possible before the practical work of exploration is undertaken. The plant explorer should not regard himself as simply a collector of potentially useful novelties or curiosities: he is a research worker consciously seeking to understand and record the bases of the adaptation to their general and specific environment of the plant forms and agricultural systems and methods which he encounters. He can do this best only if he carries out his practical work against the background of knowledge in depth of the ecological, human and agricultural characteristics of the

area. To assemble such knowledge must take labour and time spent in mastering the relevant literature and the reports of earlier investigators. Such preparatory work is essential in all research, and plant exploration is no exception.

However, planning does not stop at such technical preparation. Logistical aspects also need to be considered, for example the size and composition of the collecting team, transport needs and the various permits that will be necessary. Both technical and logistical planning are discussed in this chapter after a brief account of some of the different reasons why plant germplasm collecting may be necessary and of the various kinds of missions that may be undertaken, given different motivations, targets and constraints. Germplasm collecting tactics, logistics, preparations and procedures are also discussed by, for example, Bennett (1970), Chang *etal.* (1972), Harlan (1975), Hawkes (1980), Arora (1981), Chang (1985) and Astley (1991).

Reasons for collecting germplasm

There are over a quarter of a million plant species on earth. There is a case to be made, based on the precautionary principle, that all are equally legitimate targets for collecting. The demand for germplasm (ranging from individual genes to co-adapted gene complexes to entire genotypes or even populations) is unpredictable and dynamic. There is no way of telling what tomorrow's needs may be, and what plants may be able to fulfil them. The more diversity is conserved and made available for future use, the better the chances of fulfilling future demand. In practice, however, some prioritization is necessary, as to both species and geographic regions. Germplasm collecting can be expensive, and funds are usually limited. It is therefore important to have clear justification for any collecting expedition. If outside support is being sought for collecting, some kind of proposal will probably have to be prepared (see below, 'The collecting proposal'). Among other things, this will need to spell out in detail why the work is thought to be necessary.

The main reasons that can be put forward for collecting germplasm of a given gene pool in a given area are that:

- it is in danger of genetic erosion or even extinction;
- a clear need for it has been expressed by the users, at national level or internationally;
- the diversity it represents is missing from, or insufficiently represented in, existing *ex situ* germplasm collections;
- more needs to be known about it.

These are not mutually exclusive. Germplasm may be both threatened and useful, and there may be gaps both in collections of a gene pool and in what is known about it.

Important as germplasm collecting may be, it is essential to remember that it is not the end of the story. It needs to be seen as simply one facet of a conservation strategy that may also include an *in situ* component, for example. A successful collecting programme does not mean that one can stop worrying about conservation of the target gene pool.

Rescue collecting

If genetic diversity is imminently threatened in an area and *in situ* conservation methods are not feasible or insufficient, germplasm collecting may be warranted. Examples are the emergency programme that has been undertaken in the areas which are being affected by the Ataturk Dam in southeast Turkey and forage collecting on Mt Kilimanjaro at the high altitudes possibly in danger from global warming. Clearly, other things being equal, small populations (in numbers or spatial extent) and taxa or genotypes with restricted distributions will be most at risk in such circumstances, and will tend to be high priorities for rescue collecting. Chapter 4 deals with some of the methods that can be used to estimate the threat of genetic erosion and with recent initiatives in the worldwide monitoring of this threat.

Genetic erosion - the loss of genetic diversity - may come about for a number of often interrelated reasons. Chapter 4 also discusses some of the different ways these may be classified. Important agents include socioeconomic and agricultural change. The replacement of numerous, diverse traditionalcrop types by fewer, uniform modem varieties has become a global threat to traditional landraces of many of the major crops, especially since the 1960s. In many areas, locally important traditional food crops are being replaced by exotic staples or by cash crops. In some cases, agriculture is abandoned completely, as rural populations leave the land and drift to the cities. It is increasingly being recognized that the loss of cultural diversity that often results from socioeconomic change can be an important factor in the loss of biodiversity (e.g. McNeely, 1992).

Irreversible loss of genetic diversity can also be caused by the overexploitation of a species in the wild, for example by overgrazing in the case of forages or by uncontrolled harvesting from their natural habitat in the case of medicinal plants, firewood species, timber trees, etc. The exploitation of a particular wild species (e.g. a timber tree in tropical rain forest) can lead to the incidental removal of other, non-target species. This can extend to complete habitat destruction. Dam and road construction, the spread of cities and the cutting down of tropical rain forest for ranching are other examples of processes leading to habitat fragmentation and loss.

The occurrence of natural calamities such as disease epidemics, extended drought periods and floods can also result in the loss of genetic diversity. Often, these are exacerbated, if not actually caused, by human interference. Wholly artificial calamities that can threaten biodiversity include pollution (including the sort that many believe will result in global warming) and the introduction of alien organisms (e.g. competitors, predators, pests). Wars and civil disturbances have also led to genetic erosion, as the communities which developed and maintained landraces and managed forests and rangelands are dislocated and dispersed.

Collecting for immediate use

Local communities are continuously collecting germplasm for immediate use. This ranges from farmers exchanging planting material, as they have done for millennia, to local people collecting tree seeds from the wild for community forestry projects. However, in the formal sector, 'using germplasm' in general means incorporating it into a crop breeding or plant introduction and selection programme. Plant breeders usually maintain their own active collections consisting of carefully selected genotypes, but there is a continuous need for new, specific traits and combinations of traits in introduction, selection, domestication and improvement programmes, allowing new problems to be solved and new demands to be met. A close linkage between germplasm collecting and germplasm use has often proved to be the most effective way of guaranteeing its conservation.

Modern biotechnological tools have dramatically increased the possibility of transferring genes from one species to another. One of the immediate consequences is a widening of the pool from which a specific gene can be drawn. This means that users will increasingly be interested in species which are taxonomically and genetically less closely related to the species with which they are primarily concerned, e.g. material in the tertiary gene pool of crops as well as the primary and secondary (Chapter 6). However, there are useful species beyond the wild relatives of crops (IVCN, 1992). Such germplasm often does not need much enhancement to make an impact. Many species are used by communities and their livestock but do not reach the status of crops. Forages, multipurpose trees and many wild fruits are examples. These are increasingly becoming the target of systematic collecting. Some 25,000 plant species have been used in herbal medicines. Other species are important in land management and habitat restoration or rehabilitation, or as the 'keystones' of ecosystems. 'The reintroduction of plants will become an increasingly utilized strategy in plant conservation and protected area management' (Maunder, 1992). For a germplasm sample to be useful in a crop breeding programme it may be sufficient for it to include at least one copy of all common alleles. For other uses, in particular if germplasm samples are to be used directly as adapted populations, for example in a reintroduction programme, this may not be sufficient, and it may be required for samples to be accurately representative of allelic frequencies. As Chapter 5 discusses, this may require somewhat different sampling strategies.

One possible source of useful germplasm is existing *ex situ* collections, either within the country or abroad, which have been characterized (and possibly evaluated) or which include material from geographic areas or habitats likely to harbour desired traits. If the required material is not available in gene banks, it may be necessary to collect it. For example, if cold resistance is required in a particular crop, and landrace material or wild relatives from high-altitude or high-latitude areas is not available in existing collections, such regions would be high priorities for collecting. Clearly, if material of the target species from particular areas has already been collected, an especially strong case will need to be made for new collecting there. It is possible to make such a case if, for example, the material in gene banks is unavailable to the prospective user or available only in inadequate quantities, for example because of low viability. Many older samples were not collected with a view to reflecting variation within the original population (e.g. perhaps only a few individuals were collected at a site, or selective collections of particular phenotypes were made) and, in addition, may have undergone genetic drift and erosion during storage. Documentation may have been inadequate. Also, since sometimes germplasm is only collected from more easily accessible sites within a region (e.g. along roadsides or in markets), careful analysis will be required to judge the true ecogeographic coverage of past collecting. Repeat collecting may also be necessary if it is wanted to estimate genetic erosion in an area (see below).

Gap-filling for future use

Immediate user need is an important reason for collecting, but material not considered particularly useful today may tum out to be vital tomorrow. Agronomic problems and priorities change, ecosystems now believed to be safe may need rehabilitation in the future. Potential future use is also a legitimate justification for collecting germplasm. Within gene pools, because much genetic variation is associated with variation in environmental factors, ecological conditions which are not represented in existing collections will be accorded high collecting priorities, as well as missing genotypes and taxa.

There are, however, cases of a 'random' distribution of genes over the geographic range of a crop. Examples include cold tolerance in rice germplasm from tropical regions and the occurrence of disease resistance in germplasm from outside the geographic range of the pathogen. Collecting targeted on areas characterized by under-represented ecological conditions or of high environmental, taxonomic or genetic diversity is therefore not enough, and there should also be adequate overall coverage of the geographic distribution of gene pools. Such gap-filling (like re-collecting in inadequately covered areas) is increasingly important in the major food staples that were the targets of worldwide collecting during the early days of the plant genetic resources conservation movement.

Research

Developing a comprehensive knowledge base of the target gene pool is an important motivation for collecting. Germplasm is often needed so that particular research problems may be resolved. Examples of such problems are the mating systems of species, their taxonomic boundaries, the evolutionary relationships among taxa, and where and how cultivated forms were domesticated. Taxonomically unique or isolated, rare and narrowly endemic species often deserve a high priority in research collecting. The development of an appropriate sampling strategy will be considerably facilitated if there is adequate knowledge of the distribution of genetic diversity among and within populations, such as may emerge from preliminary research collecting (see below). Collecting for research purposes will require a somewhat different approach from conservation collecting, a topic that is explored further in Chapter 6.

Opportunistic collecting

Germplasm is sometimes collected on an opportunistic basis during a mission originally targeted on quite different species, characters or ecological conditions. Striking phenotypic features, occurrence in unusual situations and novel or interesting local uses are reasons that can lead to such collecting. Germplasm collecting may also be an incidental part of other activities, for example ethnographic studies, or botanical studies mainly concentrating on the collecting of herbarium specimens.

Types of collecting missions

Because of resource constraints, many collecting missions organized by national plant genetic resources programmes have very long and varied lists of target species. Typically, all the field crops grown in an area will be sampled, or all the forage species. This stands in marked contrast to the type of collecting generally organized by plant breeders. Such missions generally have a sharp focus on particular gene pools, species or even genotypes. Of course, these are the ends of a continuum, rather than rigid categories, and an expedition or programme will often contain elements of both strategies. Whether the target species are wild or cultivated will also fundamentally affect the character of the collecting trip, and thus the planning that will be needed. Also important is whether the trip is an intial survey/exploration or a return visit. Finally, the modalities of collecting will to some extent depend on the character of the organization(s) involved.

Multi-species vs. species-specific collecting

In a multi-species collecting mission, a region is targeted and an attempt is made to sample as much as possible of the diversity of as many species as possible. Such missions may be described as being area-driven. Usually, they are planned when no systematic collecting in the area has been conducted before and/or when the area is difficult to reach and future visits are therefore unlikely. The motives for multi-species missions have frequently more to do with conservation than immediate use, an extreme example being emergency rescue collecting in areas imminently threatened by genetic erosion.

Some problems with this kind of collecting should be noted. The most important is the relatively restricted knowledge the collectors are bound to have of many of the species they will be dealing with. This means that it will not be possible to follow an optimal sampling strategy for all the species, interesting and perhaps unique material which an expert would have recognized will be missed and the information on each sample will not be as complete as it might have been. It will therefore be all the more important to tap the large store of indigenous knowledge about plants and the environment maintained by local communities. Furthermore, it may not be possible to collect many potentially interesting species or landraces within the course of the mission because of differences in maturation time. Finally, different kinds of species may require radically different collecting techniques and even equipment. For all these reasons, a multi-species collecting mission will sometimes need to be focused at least to some extent, usually on a 'plant category'. Examples might include collecting Andean root and tuber crops in Ecuador or forages in the semiarid regions of Kenya.

Species-specific (or gene-pool-specific) missions, in contrast, tend to be driven by the eventual users of the germplasm, typically breeders and plant introduction people.-The targets of such missions may be relatively broad (e.g. wild *Phaseolus* spp. in southern Mexico) or very specific indeed (e.g. the high-lysine gene in barley in the highlands of Ethiopia), in which case specialists like pathologists, entomologists and microbiologists may also be involved. Generally, species-specific missions are less complicated to plan than multi-species missions. The ecogeographic distribution of the target material will be known in more detail, including the specific habitats (or even precise localities) in the case of wild species, and the maturation period will be better documented and more restricted. In addition, the team members will have detailed knowledge of the gene pool and will probably be familiar with material collected during previous missions.

Wild species vs. crop collecting

There are great differences between collecting wild species and collecting crops. For wild species, the collecting window will be much narrower, because ripe seeds are generally quickly shed and are usually not available to the collector once this happens (though in some cases some collecting from the ground may be possible). In contrast, crop seeds usually stay on the plant. In any case, collecting can be done at times other than when a crop ready for harvest is in the field, by visiting harvested stacks, farmers' stores and markets. Timing will thus have to be more precise for wild species than for related crops, but there will also be more variation in fruiting time both among and within wild populations, so that repeat visits and longer stays in the field may be necessary. The sources of information on which to base decisions on timing will be different. Herbaria, for example, will be one of the main sources of data on wild species, but tend not to have much cultivated material.

Populations of wild species are also usually more difficult to find. More time will be spent looking for collecting sites in wild species collecting than in crop collecting. Populations may be widely scattered and in comparatively inaccessible places. Wild species collectors therefore tend to need camping equipment more than crop collectors. It may be possible to use herbarium and other records to locate potential collecting sites with precision during the planning stage, but the collector also needs to carefully research the habitat preferences of target taxa in order to start developing a 'search image' for likely collecting sites, as well as for the species itself (N. Maxted, pers. comm.). This will be perfected through actual field experience of populations of the target species. A search image is simply a set of indicators that appear to be correlated with the presence of the target species. The indicators could be physical (e.g. outcrops of a particular rock type or a particular physiographic feature) or biotic (e.g. a conspicuous associated species or the spoor of animals known to feed on the plant). For tree species in open communities, the search image also includes the shape and colour of the crown (Chapter 23); in closed communities, the remains of leaves and fruit on the ground. Though the concept of the search image is most useful in the context of wild species collecting, it also has a place in crop collecting. For example, areas where landraces of the target crop are still likely to be found may be identified by the presence of so-called 'indicator crops' of traditional indigenous agriculture (Hammer *et al.*, 1991). As the collecting mission progresses and the search image is refined, time spent searching unsuccessfully for collecting sites will probably decrease.

Within wild populations, individuals may be widely scattered, few, small andJor inconspicuous. Again, with time in the field the collector will develop a search image for the target species, but it will still generally be more time-consuming collecting a given number of seeds of a wild species than of a related crop. However, wild species are generally more outbreeding than related crops, so, other things being equal, it may be acceptable to collect fewer individuals at each site and at fewer sites. Taxonomic identification will be more difficult than with crops. Some of the general problems and some possible aids to identification are discussed in Chapter 11. On the other hand, intraspecific variation is usually much more extensive and complicated in crops, leading to a variety of often contradictory approaches to its classification (Chapter 7). Collecting herbarium specimens for confirmation of field identifications is essential in wild species collecting but rarer in crop collecting. At the ideal time for seed collecting, however, it may be almost impossible to accurately identify plants, because this often requires the examination of floral structures. This may necessitate two-stage collecting, as described below.

Different kinds of passport data descriptors are needed for crops and wild species, which usually means that at least partly different collecting forms are used (Chapter 19). Wild species collectors tend to gather more ecological information at collecting sites. Though indigenous knowledge will be important in all collecting, it is essential in crop collecting (Chapter 12). As described in Chapter 18, the participatory methodology that this requires can be time-consuming. Compared with wild species collectors, crop collectors will tend to spend more time at the collecting site, in discussion with local people, than looking for and travelling between sites.

Crop collectors have a wide range of possible sources of germplasm on which to draw. The ideal is collecting from farmers' fields, gardens and orchards at harvest time, but farm stores, markets, shops and even family seed companies (Crisp and Forde-Lloyd, 1992) are legitimate and useful sources. Though crop collectors are more likely to visit markets, these can also be useful to wild species collectors. Fruits harvested from the wild, for example, can often be found in local markets, as well as some non-germplasm products of wild species (e.g. leaves or bark of medicinal plants, wood from timber trees, etc.). In interviews, these can be used to locate populations. Markets are often good sources of information on the diversity (both interspecific and intraspecific) available in the area they serve. They are sometimes the only sources of germplasm. They can serve a large hinterland, making them ideal first collecting stops in a target area. The areas covered by different markets are also often a good basis on which to divide up a target region for stratified sampling.

There are also problems associated with collecting from markets. They often contain a biased sample of the material available at large, as farmers may grow some crops and landraces exclusively for home consumption. The material on market stalls often consists of a number of populations mixed together and some postharvest selection by the farmer may have occurred. There can certainly be genetic differences between material sampled at random from farm stores and the material that is selected by farmers from their stores for planting (Voss, 1992). Also, the material in markets may come from an area quite distant from the collecting site. It will be impossible to record many morphological details and such sampling information as the number of plants collected. Material collected in markets (and farm stores) may have low viability compared with freshly harvested material, and larger samples than normal should be collected. Ambient conditions can be used to estimate how much loss of viability is likely to have occurred in market samples since harvesting (Chapter 20).

The differences between collecting wild species and crops, in particular as regards timing, mean that it is usually difficult to collect both categories during a collecting mission. Perhaps the most common case of this is collecting the crop together with its weedy relatives and any hybridization products.

Single-visit vs. multiple-visit collecting

Most collecting projects consist of a single, fairly short visit to the target area. Shortage of resources usually militates against repeat visits. However, there are several reasons why it may be necessary for collectors to plan to visit a target area more than once.

There may be considerable variation within a region in the timing of fruiting, due to latitudinal, altitudinal and climatic differences. For example, the fruit tree *Uapaca kirkiana* fruits in June in southern Malawi but in January in the north of the country, a distance of about 600 km. The peak harvesting time of wheat and barley may differ by a month or more within relatively restricted areas in mountainous regions such as the Atlas Mountains or the Himalayas, depending on altitude. A single, relatively short, visit may result in missing later- and earlier-maturing material, within a population as well as among populations. In species with indeterminate flowering, fruits produced at different times may be the result of pollination by genetically quite different sources. If there are two or more growing seasons in the region, material specifically adapted to one may be missed, though in the case of crops it may be available from farm stores. If the visit is too early or too late for seed collecting, vegetative or *in vitro* collecting may be possible, or local people or organizations may be commissioned to collect seeds at the next opportunity. Otherwise, a return visit by the collecting team will be necessary.

Year-to-year variation will also be overlooked by single visits. Collecting the same wild population of an annual forage in a below-average rainfall year and in an above-average year may well recover significantly different variation. In some years, it may not be possible to collect at all, for example if rainfall has been particularly low or pest populations particularly high. Some species have alternate flower type in successive years. If populations are small and net reproductive output poor; it may not be possible to collect the target number of individuals in anyone year without adversely affecting the demography of the population. Collecting would then have to be spread over a number of years (CPC, 1991).

As mentioned in the previous section, it is often impossible to correctly identify wild plants at the ideal time for germplasm collecting. One possible solution is to defer taxonomic determination to the stage when the collected material is grown out for multiplication or characterization. However, this may considerably delay use of the material. Anyway, in the case of the wild relatives of some root and tuber crops, it may be difficult to even find the plants when vegetative propagules are ready for collecting, as the tops will have died back. A better solution, if resources are available, is to organize the collecting in two stages. At the preliminary, exploration or reconnaissance stage, which is carried out at flowering time, target populations are located, the material identified (or, at any rate, herbarium specimens collected for later identification) and the site (or even individual plants) marked. This may also be the best time to collect microsymbionts (Chapter 26). The sites are then revisited at a suitable time for germplasm collecting. An additional advantage of a reconnaissance stage is that it will make it easier to accurately estimate the optimal time for germplasm collecting.

A preliminary survey visit could also involve collecting material for genetic diversity analysis, the results of which could then be used to formulate a more efficient germplasm sampling strategy. The material collected could be leaf fragments to be used in isozyme or deoxyribonucleic acid (DNA) variation studies or germplasm to be characterized for morphological characters (Chapter 6). Such survey work will tend to be of the sort described as coarse-grid by Bennett (1970) and Hawkes (1980). This involves collecting systematically (typically every certain number of kilometres) on a broad scale, covering all major environments. It is followed up with fine-grid collecting in specific areas of interest as revealed by analysis of the material collected.

The exploration stage could also be dedicated to the acquisition of socioeconomic, ethnographic and ethnobotanical data, in particular if adequate background information in these fields is not available from the literature. 'Gatekeepers' and key local collaborators may be identified, market days noted, harvesting time pin-pointed and a check-list of landrace names begun. All this would make a later germplasm collecting visit more efficient.

Repeat visits will also be necessary to monitor genetic erosion at a site or in a region (Chapter 39). This could be done by re-collecting and comparing levels of genetic diversity in the two samples, as measured by morphological, biochemical or molecular markers. Indigenous knowledge could also be tapped, for example by comparing the number of different landrace names recorded during the two visits (Guarino *et al.*, 1992) or by actually asking local people if they used to grow landraces in the area which have now disappeared.

Institutional (formal sector) DB. *community (informal sector) collecting*

Not all germplasm collecting is organized centrally and carried out by formal sector institutions such as national gene banks, agricultural research centres (national and international) and the like. There are also informal, local systems of germplasm exchange and improvement in which farmers participate on a continuous basis, as they have done since the beginning of agriculture. The formal sector has not always fully recognized the crucial role such systems have played in the development and conservation of crop genetic resources. This is changing, however, as the work of local non-governmental organizations (NGOs) (Chapter 37), community groups and other grass-roots organizations in the field becomes more widely known, and as the activities of subsistence farmers themselves are better and more fully documented.

The different approaches of the formal and informal sectors in safeguarding diversity, from collecting to use, are summarized by Mooney (1992). The key difference is that the institutional strategy has largely been one of *ex situ* germplasm storage in gene banks, while the community strategy is generally one of *in situ* conservation. Mooney (1992) describes the latter as follows:

> Cultivars are kept as part of the farming system or, where possible, in small plots for endangered cultivars and/or seed samples are cleaned, dried, stored under cool/dry conditions within the community and monitored by local people knowledgeable about the species.

This difference in emphasis is reflected in how germplasm exploration and collecting is done. Thus, the institutional strategy is described as being based on large-scale ecogeographic surveys concentrating on globally important species. Collecting missions are said to be of relatively short duration and to cover relatively large areas, so that anyone community will generally be visited only once. Collectors are mainly crop-specific specialists, often from outside the country. Evaluation is carried out in laboratories and research stations. In contrast, the community strategy is described as being based on consultations with local plant-users, a long-term exercise of survey and monitoring covering locally important species within a socioecological unit. Collecting is community-based, with little if any outside involvement. It is continuous, taking place over the whole growing season, for example, rather than at a single point during it. Evaluation is based on indigenous knowledge gathered in discussion with local users, and germplasm is documented using local classification systems and languages.

These are somewhat extreme characterizations of the two approaches. Thus, it is generally recognized that collectors should take into account not just ecogeographic but also socioeconomic and cultural factors in planning their work. The two sectors are beginning to borrow methods and techniques from one another, so that the differences in their approaches are becoming less and less marked and their complementarity more obvious. People from local communities are being trained in conventional crop genetic improvement and formal sector collectors in the use of novel social science methodologies such as participatory rural appraisal. The importance of indigenous knowledge in plant genetic resources documentation is increasingly being recognized by the formal sector, and that collecting must be an active collaboration with local communities for pragmatic as much as ethical and legal reasons.

The formal sector is thus slowly realizing that collecting does not necessarily have to take place in discrete missions setting off from a central place and returning after a few weeks in the field. A national gene bank could work through locally based extension or forestry services, traditional institutions, farmers' organizations, grass-roots NGOs or schools, for example. It would need to provide training in sampling strategy, seed handling and documentation and possibly some material (collecting bags, maps, collecting forms etc.) and funds, but could then rely on a network of trained people within such organizations to do the collecting in particular target areas and forward samples for long-term storage. A national programme could even employ the media (newspapers, radio, posters, etc.) to elicit germplasm directly from growers (Chapter 39).

Before setting out: technical planning

Once the decision has been made that collecting is necessary, the technical and logistical planning can begin. The aims of technical planning are:

- to develop a sampling strategy appropriate to the target region, species and plant parts (seed, vegetative propagules, pollen, etc.);
- to ascertain the optimum timing for collecting;
- to decide what collecting equipment and techniques will be used;
- to assemble the documentation it will be necessary or useful to take to the field.

Chapters 5 and 6 discuss the elements of a basic sampling strategy and some of the reasons for its modification. Refinement of such a strategy to suit individual cases requires research. The starting-point for this research is previous collecting work. Chapter 8 deals with obtaining information on existing germplasm collections. This will include: (i) passport data, which should say exactly where and when conserved material was collected, and can be used to estimate its adaptation and phenology; and (ii) characterization and evaluation data, which in conjunction with passport data can be used to pin-point the occurrence of specific traits and to describe the pattern of distribution of variation.

Information on the environment will also be necessary. It can show where climatic or ecological conditions exist which are likely to be associated with morphological or physiological traits of interest (e.g. cold tolerance in high-altitude areas) or which have not previously been explored. Environmental information (including topography, geology, soil, climate, vegetation and floristics) will continue to be necessary once the initial decision to collect has been made. In the absence of data on the distribution of genetic variation from previous field studies, a collecting strategy for conservation purposes should be based on sampling the widest possible range of ecogeographical and agricultural conditions. Environmental data will also be needed to determine the timing of collecting, as variation in latitude and altitude within the region to be sampled will lead to variation in flowering and fruiting time. Chapter 9 deals with obtaining and using published environmental data. Such data are increasingly available in digital form, a subject that is introduced in Chapter 16.

The environment is an interaction of natural and human factors, of course, and the human dimension is no less important in this context than climate and soil. Crops and farming systems evolve and migrate in the hands of people. Local communities use and protect wild plants. Human diversity and biodiversity are thus inextricably linked. A knowledge of the socioeconomic setting (Chapter 9) of the target region and of its history and ethnography (Chapter 12) will help collectors to understand more fully what they find and collect it more efficiently. It will also help plant breeders to use it better.

Information on the environment (natural and human) of the target area must be synthesized with information on the target taxa. This will include data on distribution, phenology, genetic diversity, reproductive biology and ethnobotany. For crops, information on pests and cultural practices will also be needed. The taxonomy and autecology of wild species will need to be researched. Collectors must have as clear an idea as possible of the seed storage behaviour of their target species. Some information on these topics will be available from the documentation of existing germplasm collections, as discussed above. Other sources are:

- literature: Chapter 13 deals with bibliographic databases in agriculture. The literature on specific topics is discussed in Chapters 7 (infraspecific classification of crops), 10 (taxonomy and ecology of wild species), 12 (indigenous knowledge systems) and 17 (pests);
- factual databases: Chapters 10, 12 and 17 (subjects as above);
- herbaria: Chapter 14.

Chapter 14 also describes, together with Chapter 15, how to bring together, organize and analyse ecogeographic data. Some of these analyses will be greatly facilitated by geographic information system (GIS) technology, as discussed in Chapter 16.

The result of technical planning should be a list of specific target areas within the overall target region, each with a list of the target material (landraces, crops, wild species) likely to be found there. There should also be a master checklist of target taxa, annotated with such information as distribution, local name, etc. (Hammer, 1991). In some cases, for example rare wild species, actual named localities will have been identified. A priority should be attached to each target area, and a tentative estimate of the optimum time for germplasm collecting according to the preferred method (seed, vegetative material, pollen, etc.). It is generally preferable to err on the side of earliness, especially for wild species, but some species can only really be efficiently collected in bulk at full maturity (e.g. many dry-zone *Acacia* species).

Not all of the information gathered in the course of technical planning will need to be taken into the field. Chapters 9,10,11,12 and 17 also make suggestions as to what documentation collectors should have with them when they set out. This will include maps of various kinds, botanical keys and other taxonomic identification aids, annotated checklists of target taxa, descriptions of pests and disease symptoms and such ethnographic information as annotated lists of important terms in local languages.

If the background information required for efficient germplasm collecting is not available in the sources outlined above, and resources permit, it may be necessary to obtain it first-hand in the field in a preliminary exploratory surveyor reconnaissance of the target area, as already discussed.

Specialized collecting equipment mayor may not be needed in the field. Most germplasm collecting is seed collecting. This is generally done by hand, either by stripping or cutting 'inflorescences or shaking them over some kind of container (e.g. a plastic tray or tarpaulin). The seeds are then stored in cotton or paper bags. Little equipment is required for this, beyond gardeners' gloves and secateurs, except in the case of tall trees (Chapter 23). Mechanical means have sometimes been employed, allowing large samples of seeds to be gathered in a short time, but they require that the target species be growing in pure stands in gentle topography (Young and Young, 1986). In any case, the damage that such methods can inflict on seeds means that they are not recommended for plant genetic resources conservation purposes, though they may be suitable if the material is exclusively for immediate use, for example revegetation work. The handling and storage of seeds (both orthodox and recalcitrant) during collecting trips are discussed in Chapter 20. Incidentally, environmental data will be needed in this connection too, to decide whether active drying of orthodox seeds in the field will be necessary.

However, environmental and species-specific factors may combine to dictate the collecting of other plant parts - i.e. vegetative cuttings (possibly *in vitro)*, vegetative propagules, whole individuals and pollen- either in addition to, or instead of, seeds. Examples include vegetatively propagated crops and forages in overgrazed or drought-stricken areas. The relevant specialized techniques and equipment, and the reasons why they must sometimes be used, are discussed in detail as follows:

- vegetative material: Chapters 21 (roots and tubers), 22 (forages) and 23 (woody perennials);
- *in vitro* material: Chapter 24;
- pollen: Chapter 25.

The germplasm collected must be adequately documented if it is to be efficiently conserved and used. This will require the gathering of data in the field (including indigenous knowledge) and, often, ancillary reference specimens. This must be planned for, as again it may require specialized techniques and equipment. These are discussed as follows:

- specimens for isozyme and DNA analysis: Chapter 6;
- indigenous knowledge: Chapter 18;
- passport data: Chapter 19;
- pest specimens: Chapter 17;
- microsymbionts: Chapter 26;
- herbarium specimens: Chapter 27.

A number of national, regional and international gene banks have accepted responsibility for global or regional base collections of particular crops. This information is available from the Food and Agriculture

Organization (FAO) and the International Plant Genetic Resources Institute (IPGRI). Arrangements should be made for the deposit in at least two such base collections of duplicates of all the material collected. (Restrictions may be placed by the authorities of the country of origin of the collection on the further use of this material, for example through material transfer agreements (Chapter 2).) This is a crucial part of the technical planning process. In the same way, arrangements must be made for the processing and storage of ancillary specimens.

Before setting out: logistical planning

The technical planning of a collecting mission will in practice be undertaken in parallel with logistical planning, the two affecting each other. By logistical planning is meant the practical arrangements that have to be made so that the technical planning can be implemented efficiently and successfully.

These arrangements will be particularly important (and time-consuming) for collectors planning to work abroad. No germplasm collecting can take place without the knowledge, agreement and participation of the national authorities. Collecting permits (Chapter 2) and export and import permits (Chapter 17) should be obtained and plans made about the use of vehicles and the participation of local scientists and support staff. Separate documents may be necessary sanctioning internal travel, ranging from letters of introduction to local government officials to a detailed 'ordre de mission'. All this should be finalized well ahead of time (at least six months may be required), but communication will need to be continuous on both logistical and technical issues right up to the start ofthe trip, for example so that a provisional timing for the visit can be altered on the basis of actual weather conditions. In some cases, it may be necessary to organize missions at relatively short notice, in response to news of mast fruiting or of good rains. IPGRI maintains databases on national plant genetic resources programmes both at its headquarters and at its regional offices, and works to facilitate contacts among national programmes, for example via crop networks.

Collectors working within their own country also need to be aware that they are part of a wider national system. For example, the collecting programme of the national gene bank may make use of the experience of forestry workers, extension staff or a local NGO in the target area, as already pointed out. Local contacts are as essential in such cases as for outside collectors. Breeders and other potential users of the material collected will need to be consulted at the planning stages and possibly included in the collecting team. Similarly, the collecting activities of a breeder, university researcher or NGO will benefit from the expertise of the national gene bank, and it will certainly be a good idea for the resulting collections to be duplicated at the national gene bank.

Size and composition of the collecting team

Institutional collecting is normally carried out by small teams of three to five people in total, sometimes multidisciplinary. One person will normally be the driver, who in the interest of safety should have no other duties. Larger teams should certainly be avoided. They tend to cause undue disruption of local life. They are also more difficult to transport, manage and coordinate, and more expensive.

It is always an advantage if the prospective end-users of the target material take part in the collecting mission, and not just when the collecting is for immediate use. A rescue or gap-filling mission organized by a national gene bank will benefit from the participation of specialists in the main target species, who will usually come from a different institute. At the very least, such people should be closely involved in the planning stages. For example, Ethiopia's Plant Genetic Resources Centre (PGRC/E) and the National Bureau of Plant Genetic Resources (NBPGR) in India, which have national responsibility for germplasm collecting, regularly carry out joint missions with breeders from other national agricultural research institutes.

Chapters 18 and 38 discuss the importance of participation by social scientists experienced in the target region along with biological scientists who are experts on the target crops, and also explore the gender issue in team composition. It is essential that at least one member of the team speak each of the languages likely to be encountered, or a lingua franca. Chapter 17 argues for the inclusion of a plant pathologist in collecting teams in some circumstances. Teams collecting wild species often include a herbarium taxonomist. A microbiologist may be helpful if collecting root symbionts is an important aspect of the work (Chapter 26). A specialist may be necessary if *in vitro* collecting is to take place (Chapter 24). A collecting team should have a leader, or coordinator, in overall charge of administrative and logistical arrangements, though clearly day-to-day decisions will be made on a consensus basis. A certain amount of division of tasks (both technical and mundane, for example cooking) and responsibilities will be necessary, and this should be worked out at an early stage. Rotas should be set up for routine, especially end-of-day, tasks (see below).

The driver should be familiar with the vehicle and its accessories, and be able to carry out basic repairs if needed. Ideally, he/she should also have some first-hand knowledge of the target region, but in any case should have experience of off-road driving in the conditions likely to be encountered (e.g. sand-dunes, rocky mountain roads, etc.).

It is essential for the efficiency and eventual impact of the collecting, as much as for ethical reasons, to see the local people and communities who agree to share germplasm and information as active participants in the collecting process, in effect *ad hoc* members of the team. This will be especially important in crop collecting. Local people should in fact be involved right from the planning stage, if possible, and the inclusion of a local representative in the collecting team as guide, go-between, 'gatekeeper' and key informant may also be considered (Chapter 18).

Transport

It is increasingly only the more remote areas that still hold valuable genetic resources. Landraces, for example, may already have disappeared from the more easily accessible villages and districts. In many regions, some coarse-grid collecting along the major roads may already have been done to rescue such material. Collectors should be ready to visit areas which are accessible only by pack-animal or on foot if necessary. A recent mission to the Aïr Mountains of central Niger, for example, was done by camel caravan and one in Lesotho on horseback. Local porters and guides will be essential in such cases. In wetland areas, it will probably be necessary to employ canoes and small boats. Advice should be sought from local people, past collectors and other recent travellers through the region on the best mode of transport in particular areas at different times of the year.

However, collecting teams for the most part move around the collecting region by four-wheel-drive vehicle, occasionally pairs of vehicles if the team is large or the terrain so rough and remote that a backup is deemed necessary. The occasionally restricted availability of vehicles is often the major obstacle in organizing a collecting mission. This is an aspect of logistical planning that should be addressed and resolved very early on. Travel to the collecting region may be in the same vehicle(s), but on occasion it may be necessary to travel by public transport to a central locality in the target region, where vehicles for travel within the region could then be arranged. Collecting vehicles usually belong to one or more of the institutes collaborating in the mission, but private and hired cars, and even taxis and public transport, have also been successfully used as a last resort.

Preferably, the collecting vehicle should have a winch and roof-rack (with a waterproof cover). It should be completely covered and lockable. Tyres suitable for off-road driving will be essential. Other necessary accessories are listed in Box 3.1.

Box 3.1
Vehicle accessories

- Basic set of spare parts.
- Toolkit.
- Two spare tyres, pump and pressure gauge.
- Puncture repair kit with plentiful supply of patches.
- Heavy-duty jack and tyre levers.
- Spare petrol cans, large funnel and plastic tubing.
- Chain or nylon rope.
- Shovel and pick.

Harlan (1975) suggests that motorcycles may be suitable collecting vehicles in some terrains. They could be transported by four-wheel-drive car as far as practical, say the head of an isolated valley, and used to collect along the valley itself, and then the procedure repeated at the next valley. Pack-animals and walking would be the alternatives. Helicopters have been used to reach very isolated or inaccessible places for botanical and germplasm collecting, but, understandably, not very often. Collectors may be able to make use of regular helicopter flights. For example, a germplasm collector hitched a ride on one occasion on the weekly helicopter flight organized by the air force in Oman to supply a series of isolated mountain villages.

The itinerary

A provisional itinerary should be drawn up at an early stage of the planning process, showing the main target areas (or even precise localities) to be visited within the overall target region, as derived from the technical planning, the roads, tracks, paths or rivers to be followed in reaching each of these and the proposed timings of each visit. The mode of transport for each leg should also be specified. Quite apart from the obvious technical reasons for preparing such an itinerary, it may be necessary for purely logistical reasons. Some countries require permits for internal travel (whether by national or foreign researchers), which may have to specify dates and places. Collecting permits may also require specific areas to be mentioned. Letters of introduction to local government officials are often useful, and their preparation again will require some rough idea of the itinerary to be followed.

Maps will clearly be needed in planning the itinerary, but local contacts are essential for advice on the feasibility of following particular routes at different times of the year (Hawkes, 1980). Such information needs to be updated whenever possible and reconfirmed before finally setting out. Local contacts will also be able to comment on the likely availability of petrol, lodging, food and water along the proposed route, which may have to be altered on the basis of such information. For example, if petrol is not available along a particular stretch of the proposed itinerary beyond the capacity of the vehicle tank, then clearly either spare petrol cans would have to be procured for the mission or an alternative route or mode of transport found. If lodging is unlikely to be found, the team will have to camp out, and equipment and supplies will be necessary. If these are not available, again the route will have to be changed. The final proposed itinerary will thus be a pragmatic compromise between the ideal based on the technical planning and what will actually be feasible on the ground given the available resources. It will no doubt have to be adapted further in the field, as unforeseen problems and opportunities arise.

Sampling intensity along the proposed itinerary will vary according to the strategy being followed. Where the target species and the environment are relatively uniform, or if only the genetic variation associated with broad geographic variation in environmental factors is of interest, one can plan to collect relatively infrequently, perhaps at regular, predetermined intervals (e.g. every 10 or 20 km], on a coarse-grid basis. Where the target species and the environment are variable - and that includes the human (cultural) environment - one can plan to sample relatively more frequently. For wild species, this might be whenever a new, distinct combination of ecological conditions occurs; for crops, it might be in each market area. If research at the planning stage (or, indeed, previous collecting or a preliminary survey) has highlighted specific genotypes or specific areas of particular interest, or if the focus of the collecting is variation within a given agroecological zone, the sampling could be of a more intensive character in some areas, i.e. fine-grid. Sampling intensity can be used to estimate the likely number of samples that will be collected, a figure that can usefully be included in the collecting proposal.

In practice, the most common procedure will be a combination of coarse-grid and fine-grid sampling, with the team staying for a certain period in one locality, using this as a temporary base (with a fair degree of intensive sampling within a readily accessible distance), and then moving on to another target locality. There would be further collecting, on a systematic basis (with the interval depending on environmental heterogeneity), when travelling between the localities. Advantage could be taken of stops at such temporary bases to dry material (seed samples and herbarium specimens) and arrange for the dispatch of samples to the gene bank if necessary.

In addition to temporary bases, most missions will have some kind of home base, a place where the team can assemble and equipment and supplies be brought together. Various necessary end-of-mission activities can also be carried out here, such as packing seeds for dispatch and completing passport data forms (see below). In regions where the climate necessitates active drying of seed, a base should be found where this can be carried out. The base may be the national gene bank or its substations. If these are too far from the collecting region, a suitably equipped local institute could act as base. As a last resort, hotel rooms and private houses have successfully been pressed into service as collecting bases. Arrangements for a particular place acting as base should be finalized at the planning stage.

Duration of the collecting mission

Based on the proposed itinerary, it will be possible to estimate how long the team will be in the field. In addition, it will be necessary to schedule time at base both before going into the field and after coming back. It might be that the itinerary turns out to be too long for the time and funds likely to be available, and may have to be altered. Most institutional collecting lasts less than a month. Apart from anything else.Tt is recommended that this be the maximum time that elapses between collecting seeds and their receipt at the gene bank (Chapter 20).

A month is usually more than sufficient for single-species (especially single-crop) missions, in particular if they are well timed. However, if the target region is very diverse in climate and topography, the resulting variation in harvesting time may mean that a short visit will miss genetic diversity in some areas. Different crops and landraces may be harvested at widely different times even in a single village. If the mission is to be multi-crop, more than one visit to a given village may be necessary during the course of the mission, which will add to the overall duration of the trip. Longer missions are more expensive and may not be feasible if participants have other commitments and the vehicle is needed for other purposes. The team may have to plan to go back to base after a certain period in the field so that some members may drop out, others join, and seed samples may be dispatched to the gene bank. An important advantage of community-based collecting is that, as a continuous process, it can expect to cover the growing season(s) more thoroughly.

Equipment

The fact that specialized collecting equipment may be required has already been alluded to, and reference made to the relevant individual chapters which describe it. However, general travelling equipment may also be necessary during a collecting mission in addition to basic vehicle accessories. This will be particularly true if the mission involves camping out in remote areas, which is perhaps more common in wild species collecting, though not unknown in crop collecting. Whether camping will be necessary should emerge from careful consideration of the proposed itinerary in consultation with people knowledgeable about the target region.

Rural communities are usually extremely hospitable, but lodging and feeding a collecting team, even for a single night, may constitute a significant drain on local resources, and collectors should try to be as little of a burden, and as little disruptive of local life, as possible. On the other hand, refusing hospitality may be considered offensive in some societies. Offering to pay may be equally out of the question, though a contribution in kind to a meal, or a parting gift, may be acceptable. Collectors will need to be extremely sensitive to local customs in this as in other aspects of their relationship with rural communities. In any case, they should never count on hospitality, but be prepared to cope on their own at all times as regards food, water and a place to sleep.

An important part of logistical planning is making sure any necessary equipment, and any food supplies that might also be needed, will be available at the right place (probably the home base) in good time. General travelling equipment and supplies may be divided into camping and medical. Bennett (1970) and Hawkes (1980) give comprehensive lists of both categories. Hatt (1982) is a good general guide for travellers and also gives useful checklists of medical and personal supplies and equipment. Box 3.2 gives a brief summary of camping needs. Exactly how

Box 3.2
Camping equipment

- Tents and accessories.
- Tarpaulin and ropes.
- Waterproof sleeping-bags.
- Mosquito netting.
- Camp-beds or air mattresses.
- Small folding table and chairs.
- Battery-operated hand torches and spare batteries.
- Cooking stove (butane, solid-fuel, etc.) and spare fuel.
- Matches.
- Cooking pots and utensils, plates, mugs, cutlery, etc.
- Candles and/or lamp (battery or gas).
- Water containers (both large cans and individual bottles).

much of this equipment will actually be taken into the field will depend very much on the mode of transport and on the climate. If space is at a premium in the collecting vehicle, as might be the case if vegetative material is being collected, or much of the travelling is to be on foot, then clearly a folding table and chairs are likely to be a low priority. In some climates, a tent may well be unnecessary. On the other hand, torches and water-bottles, for example, are likely to be present among the equipment of all collecting missions, whether camping is planned or not.

Box 3.3 lists some medical supplies likely to be useful on collecting expeditions. This should not be treated as anything more than a general guide. Ready-made first-aid kits (and more comprehensive medical kits) are available on the market in many countries. These come with detailed instruction for the use of individual components, and are thus a better option for collectors than simply putting together a kit themselves *ad hoc*. Many institutes provide basic medical kits in their field vehicles. WHO (1993) provides detailed health advice for international travellers.

The collecting proposal

To put the planning into practice, funding will be needed. As has already been mentioned, whether this comes from within the collecting institute(s) or from some outside source, some kind of written proposal will probably be necessary. The collecting proposal should address the issues of what, where, why, when, how and who by including the following results of the technical and logistical planning process:

- a justification of the collecting by area and species, including evidence of genetic erosion, user need, gaps in existing collections and/or gaps in knowledge;

Box 3.3
Medical supplies

- Water-purifying tablets.
- Insect-repellent cream.
- Antihistamine *cream.*
- Antiseptic *cream* or wipes.
- Antibiotic tablets and cream.
- Fungal infection remedies.
- Antacid tablets.
- Antidiarrhoeal tablets.
- Sachets of oral rehydration solution.
- Eyewash.
- Oil of cloves for toothache.
- Lipsalve.
- Aspirin, paracetamol or other pain-killer.
- Antimalarial tablets for both prophylaxis and treatment.
- Snakebite sera.
- Disposable hypodermic syringes.
- Cotton wool.
- Splints.
- Bandages and plasters.
- Scissors.

- a prioritized list of target species or plant categories, each with a note of what plant part(s) will be collected, of any reference and ancillary specimens that will be collected, of any specialized techniques that will be used and of the proposed protocol for the division and distribution (including to base collections) of germplasm and ancillary specimens;
- a sketch map showing the location of the proposed target region and of specific target areas (and actual localities) within the region, with priorities based on an explicitly stated sampling strategy;
- an itinerary, including tentative dates, timings and proposed mode of travel;
- a description of proposed follow-up activities, e.g. characterization, evaluation and/or use of the material;
- a list of the people and organizations involved, and their respective roles;
- a budget, which will depend on such considerations as the size of the collecting team, the length of time to be spent in the field, the distance to be travelled, the mode of travel and the equipment that will be necessary.

To what outside agencies can a collecting proposal be submitted? The collecting activities of the national plant genetic resources systems of developing countries, whether in the formal or informal sector, are occasionally supported by bilateral and multilateral development agencies. National programmes the world over also collaborate with each other. Such collaboration may be on a bilateral basis, in crop networks or under the aegis of a regional structure. An example of bilateral collaboration is the Gatersleben gene bank's collecting in Cuba and elsewhere (Chapter 39). An example of a regional organization which supports collecting is the Southern Africa Development Community (SADC) Regional Plant Genetic Resources Centre in Lusaka. International agricultural research centres (IARCs), both inside and outside the Consultative Group on International Agricultural Research (CGIAR), are also possibilities. IPGRI can advise prospective germplasm collectors on the possibilities for funding and collaboration.

In the field

It is important, once in the field, to establish a daily routine to find collecting sites and to collect at the site. The concept of the search image and its importance in locating potential collecting sites, especially of wild species, has already been discussed. It has also already been stressed that an integral part of the collecting routine, both as regards locating potential collecting sites and at the site itself, will be consultations with local people, in particular when collecting crops. However, local people will also be vital in the more practical aspects of collecting: it is good practice to take every opportunity to ask about the situation ahead (e.g. where the road is going, whether it is practicable, whether petrol, water or accommodation is available in the next village, etc.), in order to confirm and supplement previously obtained information.

Once a collecting site has been identified, it must be described on a collecting form and the population sampled and also described. Some definitions are in order here. The formal definition of the *population* is those conspecific individuals among which gene flow normally takes place, i.e. an interbreeding group of plants. The spatial extent of the population will depend on the pollination and dispersal systems of the target species and requires experimental study for its estimation (Chapter 6). Therefore, for practical purposes the population is usually defined by collectors not in strict genetic terms but ecologically, as those conspecific individuals found within a restricted area under relatively homogeneous ecological conditions. How restricted? Chapter 5 presents guidelines for the minimum number of individuals that should be collected from each population. Pragmatically, this, together with guidelines on the minimum distance that should be kept between sampling points to avoid excessive sampling of clones and closely related individuals, will largely determine the minimum size of the area to be sampled. This ecologically uniform and distinct area is the *collecting site*, and the collecting form aims to document the conditions which characterize and distinguish it. In crop collecting, the site is usually the farmer's field, garden plot or orchard, or perhaps the whole village in the case of some fruit trees. In wild species collecting, it will not be so easy to demarcate. In general, however, if two adjacent areas differ in some feature of the physical, chemical or biotic environment, they should be taken as being separate collecting sites.

The *sample* is material chosen from the population (in whatever manner) for *ex situ* conservation. There may be more than one sample from a given population (separate random and selective samples, for example) and more than one species sampled at a site. Strictly speaking, for any given species, by definition there should be only one population sampled per site. Thus, distinct samples of a particular species from different microenvironments within a location, sampled according to a stratified procedure, should be treated as coming from separate populations inhabiting distinct sites, so that the nature of the microenvironmental differences can be recorded on the collecting form. In practice, to speed things up in the field, such samples are often said to come from the same 'site', but distinct *subsites* or *microsites.* This concept may also be useful in crop collecting, for example when landraces are collected from different farmers' or households' fields or plots in the same village.

Chapter 5 discusses the issues of how to select individual plants for inclusion in the sample, of the number of such plants and of the number of seeds to be collected per individual. A baseline criterion for conservation collecting is to gather a bulk sample of equal numbers of seeds from some 50 individuals, sampling at intervals along a number of transects across the collecting site. Modifications of this basic strategy to suit particular species and purposes are discussed in Chapters 5 and 6.

Reference has already been made in the context of technical planning to individual chapters dealing with specialized collecting techniques and data documentation. There may be people on the team specifically included to deal with such specialized tasks, for example a microbiologist or a herbarium taxonomist. In any case, each team member's duties at the collecting site should be clearly set out. In particular, the jobs of documenting the site and population and of actually gathering the germplasm can to some extent be separated. Chapter 22 gives an example of how this might work in practice. Though the context is one of collecting vegetative material, the principles would be the same when collecting seed. First, the limits of the collecting site must be decided on, and how exactly sampling should take place. Then, while one or two team members collect germplasm, perhaps transecting the site in different directions, another can be starting to fill in site information on the collecting form, before joining the others in gathering germplasm or, perhaps, associated samples such as herbarium material, soil samples, etc. Population information is filled in later by all collectors together, when collecting at the site is finished, along with sample information. The amount of time spent documenting site and population will vary, but certain passport data descriptors must always be recorded. A minimum set is proposed in Chapter 19. Herbarium specimens should always be prepared when collecting wild species. Samples are then labelled and packaged as necessary. Chapter 18 shows how participation by the local community in the day-to-day conduct of a germplasm collecting expedition might be organized.

The state of germplasm and other samples should be checked throughout the course of the mission as part of the daily routine. Time should be set aside for such activities at the end of each day. The most important tasks will be the following (there are details in the appropriate chapters):

- Seed and vegetative (including *in vitro)* samples should be checked on a regular basis for insect and fungal attack, and infected samples either treated or discarded.
- If seed samples (or other material) are being actively dried, the silica gel may have to be changed and dry samples removed.
- Samples of fleshy fruits in plastic bags will need to be aerated regularly and checked for rotting.
- Drying papers in herbarium presses must be changed every couple of days and dry specimens removed and packaged together in bundles.
- Samples may need to be sent back to the gene bank at various stages during the course of the mission, rather than waiting until the end.

There will also be various documentation activities to be completed, including the daily diary entry. A few descriptors on collecting forms can also be left until the end of the day (or the end of the mission), for example latitude and longitude and other data which can be read off a map on which the location of the site was previously marked. The end of the day is also a suitable time to check that all of the samples collected that day are accounted for and that the collecting numbers accompanying them tally with those noted on collecting forms and field notebook.

It is good practice to prepare a checklist of end-of-day activities and a roster assigning such tasks to team members on a cyclical basis. It will often be a good idea to hold team meetings at the end of each day to summarize and discuss findings and plan the next day's work.

Not everything can be planned for, however. Collectors can decide on a broad strategy beforehand, but will need to be flexible in their tactics in the field both to overcome unexpected difficulties and to take advantage of unexpected opportunities. Many of the difficulties will be logistical: unpassable roads, rivers in flood, vehicle breakdown and the like. Some will be technical. The visit may be taking place too early or too late in the season, for example. In crop collecting, this may require visiting more markets and collecting from farmers' stores. In wild species collecting, the decision may be made to turn the germplasm collecting mission into a herbarium survey and come back later for germplasm, or to change the itinerary to cover areas where the timing might be more suitable. If target populations are rarer than originally thought, more individuals than planned might be collected at each site. If populations tum out to be small, and it is not possible to collect the required number of individuals in each, it might be decided to collect more populations than planned to compensate. If the target species turns out to be heavily grazed or not in seed, it might be necessary to improvise a vegetative collecting method.

As for the opportunities, collectors should always be on the look-out for interesting and unusual germplasm: a population of a species (even one that is not a priority target) in an atypical ecological setting, a crop being grown or used in a peculiar way, or the odd healthy spike in an infested field. The basic strategy is to collect from the largest possible number of different and distinct local environments. These can be defined to some extent at the planning stage, but one must watch out for them in the field too. If a track presents itself that is not marked on the map, collectors must be prepared to temporarily abandon the original itinerary if this is thought likely to result in obtaining more, and more interesting, diversity of the target taxa.

Back at base

Once back at home base, on completion of the fieldwork, collectors will still need to carry out some important tasks before the mission can be deemed successfully completed. These tasks, described in detail in Chapter 28, are:

- sorting and preparing germplasm samples and any reference and ancillary specimens;
- collating, completing and editing the collecting data;
- distributing the germplasm samples, reference and ancillary specimens and collecting data.

These back-at-base tasks will require a certain amount of planning. In the first place, sufficient time and resources should be allocated to thein. Sorting samples requires space. So does ambient drying of seeds and herbarium specimens. Active drying of seeds before dispatch requires either specialized equipment or chemical supplies. A computer will be necessary for the documentation of passport. data. All these should be available at the base on completion of the mission. Some equipment and supplies may have to be brought in from elsewhere by the collectors themselves.

Arrangements should also be made for the distribution of germplasm and other samples. The agreement of institutes to accept germplasm for storage and follow-up work, recalcitrant seeds for immediate planting, *in vitro* material for processing, *Rhizobium* nodules for isolation, herbarium vouchers and pest specimens for identification, soil samples for analysis, etc. must be obtained before the mission actually starts. Recipients must then be warned of the imminent arrival of material once it has been sent. Dispatch of biological specimens will require phytosanitary certificates, which will need to be obtained once back at base.

The final task in collecting is reporting on the mission. This is crucial if potential users are to be kept up to date on the availability of germplasm in *ex situ* storage. What a mission report should contain and where it can be published are discussed in Chapter 29.

Careless collecting: two points to watch

Collecting may cause more problems than it solves. In particular, there are two dangers associated with careless collecting: the damage of fragile populations and the introduction of pests and competitors.

Excessive sampling from a small population may endanger its chances of survival. Given the likely investment of time, effort and resources, collectors will understandably be keen not to return empty-handed or with insufficient material, but a conservation ethic must be kept in mind at all times. The collector must be careful not to collect so much material from a population as to adversely affect its demography. A potential collecting site should be passed over if it is deemed impossible to collect germplasm from it without damaging the target population or the habitat. This point is clearly made in FAO's Code of Conduct for Plant Germplasm Collecting and Transfer (Chapter 2).

Also, germplasm samples may be diseased, infested with insects or contaminated with weeds. Care must be taken to prevent the movement of such pests around the world (Chapter 17). The species being collected may itself be actually or potentially noxious. Introduced species are a major cause of biodiversity loss and will probably be the biggest cause of species loss in the future (W.A. Strahm, pers. comm.). Precautions need to be taken when collecting and introducing species that could become naturalized and compete with the native flora or introgress with local species.

The case-studies

What has been presented in this chapter is perhaps an ideal model. However, rarely will it be possible to organize and run a collecting project or programme exactly as one would have wished, or indeed as was planned. Actual examples are therefore in many ways more informative than any ideal model. For this reason, the final section of this volume presents a number of case-studies chosen to reflect a wide range of species (and therefore collecting problems), geographic areas and types of collecting programmes. This is not to say that the range is exhaustively covered. However, the ten examples included here are illustrative of the variety of ways that collecting may be organized and carried out and describe how highly specific problems were overcome, which it was not possible to address in great detail in the more general chapters of this volume. The types of collecting described in the case studies are as follows:

Chapter 30	Worldwide collecting of a wide range of wild species for evaluation and selection by national and international programmes.
Chapter 31	Ecogeographic study of a tree genus with recalcitrant seeds in its centre of diversity in a collaborative project involving various national institutes and international conservation organizations.
Chapter 32	Collecting vegetatively propagated root and tuber crops of local importance by a national programme.
Chapter 33	Collecting vegetative material of a crop and its wild relatives in its centre of diversity by an IARC in collaboration with a national programme, with later *in vitro* culturing in a neighbouring country for disease screening and safe transfer.
Chapter 34	Worldwide collecting of a major cereal staple and its wild relatives over many years by an IARC in collaboration with national programmes.
Chapter 35	Collaborative collecting of the wild species within the genus of a crop, all geocarpic, by a number of national programmes within the geographic region of the distribution of the genus, with support from other interested national programmes and IARCs.
Chapter 36	Collecting rare and endangered local wild species by a botanic garden.
Chapter 37	Collecting socioeconomically important forestry species by an NGO.
Chapter 38	Collecting a staple root crop and the indigenous knowledge (IK) associated with it by an interdisciplinary, international team.
Chapter 39	A national institute's collaboration with several other national programmes on a wide range of crop gene pools.

Conclusion: the ingredients of success

In summary, the success of germplasm collecting programmes may be seen to depend on keeping in mind the following basic points.

Plan well ahead

The importance of thorough research and planning in the success of field collecting cannot be overemphasized. Information on the distribution of the target species (and of genetic variation within the species), on breeding system, on fruiting time (and how this varies geographically), on seed storage characteristics and on appropriate collecting techniques will all be crucial to the success of collecting. Also important will be background data on the physical, biotic and human environment of the target area. As a general rule, at least as much time should be allocated to planning and preparation as to field collecting. Usually, planning will take considerably longer.

Involve local people

Active local participation is an ethical (and, increasingly, a legal) imperative, but the efficiency of collecting will also depend on it, in particular crop collecting. Deciding on the timing of collecting, locating target populations, developing a suitable sampling strategy and documenting the collection will all benefit from local participation.

Be prepared to be flexible

Good timing of collecting is essential for wild species, especially those that shed their seeds over a short time span. A profile of seed maturation and how it is affected by location (latitude and elevation) and climate should be developed for each target species. This may not be enough, however. Local observers can be engaged to keep a watch on weather conditions and the developing fruiting season. The collecting team should be ready to go into the field at short notice if local sources report that the fruit is shedding early (e.g. due to a hot, windy spell) or is being destroyed by seed- or fruit-eating animals. It should be flexible enough to make last-minute changes in the itinerary to take account of new information while in the field.

For woody species, collecting in mast years is an efficient use of resources. Considerably more seeds can be collected for a given input of time and resources. The likelihood is also increased that the seeds collected are of the best genetic quality (due to a reduced proportion of selfed seed) and of high viability (due to a higher proportion of fertilized ovules and lower incidence of insect attack). Again, there should be enough flexibility in a collecting programme to allow missions to be undertaken at relatively short notice in a year of mast seed production or postponed in poor seed years.

Develop a search image

The speedy location of populations of target species is essential to the success of collecting expeditions. A considerable amount of time can be wasted searching for populations if research has been inadequate and a rudimentary search image has not been developed. It is always an advantage if collecting teams include an experienced person capable of rapidly and accurately locating target species and ascertaining whether they are carrying a useful seed crop (i.e. one in which the desired quantity of viable seeds can be efficiently collected within a reasonable period).

Choose collecting and processing techniques with care

In any given situation, the collector must be able to quickly determine the most efficient harvesting technique for each species and processing technique for each sample. With woody species, it may be necessary to employ two or three different harvesting techniques for a population. Seed extraction procedures may vary for a species depending on the maturity of the fruit. When dealing with species that are not well known, the ability to, develop and improvise new collecting and processing techniques may be crucial to the success of the mission.

Document the collection scrupulously

Germplasm without passport data (both indigenous knowledge and the results of scientific measurement) is less useful than it could be. Collecting forms should be filled in conscientiously, at the collecting site. In all crop collecting and much wild species collecting, this will require consultations with local people. All the descriptors in the recommended minimum set should be recorded, and any others as time allows and circumstances require. Samples should be numbered legibly and unambiguously.

Take trouble with samples

The material collected should be of the highest possible quality (i.e. viability), and it is crucial to keep it that way. The key to preventing deterioration of samples is frequent inspection. At the first sign of deterioration, appropriate remedial action should be taken. If fruit samples begin sweating or show signs of mould, they should quickly be opened up and dried out and affected material discarded if necessary. It is imperative that samples of clean, dry seeds be stowed in a manner that prevents wetting. In all cases, it is best to get samples back to the gene bank as rapidly as possible, and in any case within a month.

Think about safety

Due attention to safety is vital for continuing, successful collecting programmes. This may require that vehicles travel in pairs on certain routes, and that some areas be avoided altogether. When necessary, collectors must be provided with, and make use of, safety equipment and clothing. Particular care needs to be taken in the operation of vehicles, secateurs and rifles, and in tree climbing.

Follow up

A successful collecting programme does not end once the team is back from the field. The germplasm (and associated data) must be properly stored in duplicate base collections, voucher specimens must be deposited in herbaria and identified as necessary, and so on. Collectors themselves often follow up their fieldwork with characterization, evaluation and other experimental work on the germplasm they have collected. A report must also be written, and circulated widely. so that interested scientists worldwide may be informed of the availability of potentially useful material.

Follow the Code of Conduct for Plant Germplasm Collecting and Transfer

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