Collecting tropical forages

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Systematic exploration for species of grasses, legumes and browse plants to be used in tropical pasture development is a relatively new phenomenon. It was not until the early 1950s that many tropical areas of the world began to be traversed in the search for new and useful pasture species, a search that has not stopped. This new germplasm and improved livestock management have led to a boom in tropical pasture development. There are even instances where formerly degraded and unproductive lands have been returned to pastoral production by adopting the new technologies. The relative newness of tropical pasture species development can be illustrated by two Australian cultivars. Until the mid-1960s, *Stylosanthes hamata* was known only as a somewhat weedy component of seminatural pastures in the Caribbean. It was certainly not considered to be a major pasture legume anywhere. However, an introduction from Maracaibo, Venezuela, into a *Stylosanthes* evaluation programme of the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, was quickly recognized as having enormous potential in dry tropical pastures. It was released in 1973 as cv. Verano and has had an enormous impact in pasture development, first in northern Australia and now in the Sahelian zone of West Africa and parts of India. Its success has led to further detailed collecting of *Stylosanthes* in northwestern Venezuela in the hope of finding even more productive material.

Another example is the legume *Cassia rotundifolia*. Many early botanists in subtropical South America commented on its abundance in native pastures. In 1947–48 the first Australian mission to South America collected seed, but more importantly pointed out the potential of the species. Further introductions took place and some initial evaluation was done but it was not until 1984 that cv. Wynn was released. This example shows that, even if a plant is identified as being useful, it may still take some time to make its way through the introduction, evaluation and selection system. There is no telling how many other species are just waiting to make a similar impact to *C. rotundifolia*, for example *Aeschynomene villosa*, *Demanthus virgatus* and *Digitaria milangiana*.

During the early years of collecting tropical forages, teams tended to cover large distances quickly, sampling simply wherever an interesting plant or site was encountered. Strickland (1974) covered a wide range of environments in eastern and southern Africa by following collecting routes designed to traverse a range of soil types and altitudes in the various vegetation types outlined by Rattray (1960). Altogether, almost 45,000 km were covered by four-wheel-drive vehicle, starting in Mombasa, Kenya, and ending in Durban, South Africa. The resultant grass collection amounted to 118 species in 36 genera, in particular *Anthephora*, *Brachiaria*, *Cenchrus*, *Cynodon*, *Digitaria*, *Panicum* and *Urochloa*. The legume collection totalled 138 species in 38 genera, the more important of which were *Dolichos*, *Indigofera*, *Lotononis*, *Macrotyloma*, *Rhynchosia*, *Trifolium*, *Vigna* and *Zornia*. A somewhat more detailed strategy in exploration is to conduct a series of missions covering essentially the same terrain and collecting sites. Reid (1983) traversed Mexico in such a way that the maximum number of contrasting regions could be sampled on a recurrent basis over a period of two years. Some sites were visited up to five times, not only to ensure that ripe seeds of target species would be collected but also to guarantee that all species of likely potential were in fact sampled.

The exploratory approach has been superseded as both geographic regions and individual species have become better known, but it still has value in regions that are relatively poorly known botanically and where there is need to establish the general state of the environment, i.e. land degradation, level of overgrazing, human encroachment, etc. There are still significant regions that have not received any attention from forage collectors and which may therefore warrant going through an initial exploratory phase. Schultze-Kraft and Giacometti (1978) argue that:

> there are two important reasons for continuing tropical pasture germplasm collecting: (a) the need to obtain the maximum possible genetic variability, in order to proceed with the selection of the most promising materials; and (b) the need to guarantee the preservation of the available genetic resources, *while they still exist*. An important reason to stress the latter need is the very clear evidence that genes of tropical species are being lost. On more than one occasion, upon returning to a collection site of especially promising genetic material, it has been found that the material no longer exists.

Most experienced tropical forage collectors would agree as to which regions remain to be explored. The order of priority may differ, and indeed change as research develops, but institutions, both international and national, with a long-term commitment to tropical pasture plant collecting (e.g. the Centro International Agriculture Tropical (CIAT), CSIRO's Division of Tropical Crops and Pastures, etc.) have clear ideas as to which countries or regions remain to be explored. In Africa, for example, Angola, Mozambique and Sudan could be mentioned. Deciding what species to collect is more problematic. Some collecting missions deal with one or two genera which are required for particular purposes. Others will collect all variations in genera known to be used as pasture plants, and in addition species unknown in agriculture if they seem to be eaten by livestock and possess agronomically important environmental adaptations or morphological attributes. As demands on existing cropland increase and the more productive pasture lands are ploughed up, increasing emphasis will be placed on the upgrading of pastures by the introduction of such species. The overgrazing of traditional grazing lands and general land degradation are also creating the need for new species to fill 'niches' where at present no species can be recommended. While progress has been rapid, there are still many habitats, such as semiarid cracking clays, acid semiarid soils and salt-affected lands, where new species are urgently required. Further, as management improves (fencing, controlled herding, pasture spelling and fertilization), so the option of using improved species becomes ever more valid.

Broad-spectrum collecting puts a particular strain on the collector's skills in field identification of material. All too often material has been collected and stored in gene banks without adequate taxonomic characterization or verification (Marshall, 1989). Many accessions are also clearly mixtures of species when grown out. There may be various reasons for this, though few excuses. Identification aids may be lacking or of poor quality, especially for difficult and little-known groups. Many of the climbing legumes intermingle and it is difficult to physically separate them. Diagnostic features (e.g. flower colour and structure) are often absent at pod set and the material may be too dry to make a satisfactory herbarium voucher. Ideally, the collector would visit the collecting site on a number of occasions to overcome these problems, but in practice this is rarely possible. The collector should therefore be as familiar as possible with the species in the areas to be visited which are of known or potential forage value. This means surveying the literature, including Floras, ecogeographic studies and vegetation studies. Most importantly, however, it means visiting herbaria.

On visiting herbaria, many collectors are surprised to find how many of their target species have been collected extensively by botanists and are well known to them. Examination of herbarium specimens helps not only in becoming familiar with the material but in pin-pointing potential collecting localities and in establishing the optimum time for collecting. Unfortunately, it is often not possible for the collector to visit those herbaria that hold the major collections of the target species. For example, although the National Herbarium at Nairobi has excellent holdings from eastern Africa, any collector needing an in-depth picture would also need to spend some time at the Royal Botanic Gardens, Kew. The situation is somewhat similar with many Latin American floras, where the most extensive holdings are in the herbaria of either the Missouri or New York Botanical Gardens. An example of the value of preliminary herbarium work is given by Pengelly and Reid (1988). They examined approximately 800 herbarium specimens of legumes from Papua New Guinea considered to be of potential as forage plants and established a database containing such information as stage of maturity and time of collecting, geographic coordinates, altitude, soil type and rainfall. From this, a collecting route was planned and a mission undertaken by the senior author. The resultant collection contained samples that were agronomically interesting because of their climatic requirements, acceptability by livestock or occurrence on particular soils. This collection is likely to prove of great value to pasture workers in the African and American tropics.

Herbarium surveys are useful in determining the best time to collect. The timing of collecting missions is critical when seeds are to be collected but clearly more flexible if vegetative material is the target. In the former case, collectors have to time their activities in an area to coincide with the availability of ripe seeds of the target species on the plants, before shattering occurs. In general, this can be estimated from rainfall and day-length data but clearly more accurate information can be obtained from herbarium sheets and local informants. Recent developments in the use of *in vitro* collecting techniques not only offer alternative means of conserving and using plant germplasm but also solve many of the logistical difficulties associated with planning and executing collecting missions. In a recent collaborative project between the International Livestock Center for Africa (ILCA) and the International Board for Plant Genetic Resource (IBPGR), an *in vitro* technique was developed and applied to collecting germplasm of the forage grass genera *Cynodon* and *Digitaria* (IBPGR, 1990). By freeing the collector from the constraints imposed by the necessity to collect seeds it will be possible to be more flexible in timing the expeditions, also allowing more time in the field. Of probably even greater importance is the possibility of being able to collect, and thus evaluate, material from those grass genera that are routinely overgrazed or that set few viable seeds (e.g. *Digitaria*, *Echinochloa*, *Eriochloa*).

Acquiring pasture plants that will be used in specific environments usually involves exploring environmentally homologous regions. For example, on the broadest scale CIAT has targeted tropical, acid, infertile soils, initially in the Americas but lately in southeast Asia and Africa, as source areas of germplasm adapted to its reference areas in South America. Less extensive and more narrowly focused was the programme by Staples (1986) to collect tropical legumes in India adapted to clay soils (vertisols) and suitable for evaluation on similar soils in northern Australia. Prior knowledge of the occurrence of small areas of particular soils or vegetation types within larger soil or vegetation units makes it possible to include visits to such areas in the mission plan: discovering them at the time of collection often requires last-minute changes in the expedition schedule that it may not be possible to accommodate.

Some species are relatively common in all or part of the area sampled by a collecting mission or programme, while others require a great deal of effort to obtain even one sample. Schultze-Kraft *et al.* (1984) found that two of their target species (*Desmodium heterocarpon* and *Pueraria phaseoloides*) were among the most common native legumes of China's Hainan Island, but another (*Codariocalyx gyroides*) was quite rare. Reid (1983) attempted not only to acquire samples representing the broad range of variation in *Leucaena leucocephala* in Mexico, but also samples from all 14 *Leucaena* species. All were in fact acquired but two proved particularly problematic. *L. retura* is uncommon though very widely distributed through the arid regions of northeast Mexico; thus long distances had to be covered and many sites examined before samples could be obtained. In contrast, *L. cuspidata* was relatively easy to find, with the help of herbarium locality data, but proved to be a relic population of less than 40 plants.

A number of workers (Allard, 1970; Marshall and Brown, 1983) have suggested sampling strategies to achieve the conservation of the maximum amount of genetic variation without incurring the penalty of excessive sample numbers. The number of plants sampled per population depends on the breeding system of the target species; fewer plants need to be sampled for cross-pollinating species than for self-pollinators. However, the breeding system of many of the tropical forage species that are being collected is still not known, and it is self-evidently better to collect more seeds rather than fewer if circumstances permit (Reid and Strickland, 1983). This problem of how much to sample is without doubt the most vexing question faced by the collector. All collectors have problems putting sampling theory into practice, for a number of reasons. Few forage species are found in large, dense, evenly distributed populations. It is much more common, particularly in perennial legume species, to find individual plants thinly and patchily distributed across the habitat. It is not uncommon for collectors to report taking days or even weeks to find a single, much sought-after, ecotype.

Also, tropical forage plants are still wild and essentially weedy, and their seeding characteristics uneven. Most legumes have pods that shatter on ripening. This makes it very difficult to ensure that any given population is sampled adequately. Many experienced collectors have stories of combing over a population of legumes for hours to be rewarded with nothing more than the sight of shattered pods. Of course, it may be possible to keep returning to a site and to collect sufficient seeds at the time of maximum yield, as the author was able to do in Mexico (Reid, 1983). However, the reality is that, through lack of resources, most collectors are unable to return to a site; regrettably, the majority of collecting sites will only be visited once.

Finally, as many collectors are not only involved in the planning and execution of a collecting programme but also in the initial evaluation of the material they collect, their emphasis is likely to be on cultivar development rather than the conservation of genetic resources. Knowing that, even if only a small number of seeds are collected, the accessions will nevertheless be grown out, multiplied and evaluated, the collector will be satisfied with a smaller sample. Most tropical forage collectors adopt the attitude that it is far more important to gather diversity from as many different sites as possible than to spend valuable time gathering large seed samples from a few sites. From the point of view of pasture species development this approach has proved to be eminently successful, with many now well-advanced cultivars being produced from initially very small samples of less than 50 seeds. Examples include *Stylosanthes hamata* cv. Verano and *Aeschynomene americana* cv. Glenn (L.A. Edye, pers. comm.).

Information on infraspecific variation can also help in formulating an efficient collecting strategy, but very little is available on most wild forage species. Even where some data are available, the number of genotypes involved is usually very small. For example, in a collection of 121 accessions of *Alysicarpus* spp. classified by Gramshaw *et al.* (1987) into 19 morphological/agronomic groups, only four were represented by more than ten accessions. A number of the groups contained only one or two accessions, which would suggest that there is much diversity yet to be collected. Most of the tropical forage genera that have been studied are similar in this respect.

Each species and each area will present unique problems in sampling, but where sufficient genetic information is available it is possible to plan better sampling strategies. This is well illustrated by the research conducted on the genus *Stylosanthes*, which consists of about 44 species. Over the last 25 years much information has been accumulated on the agronomy and regional adaptation of many of these species. It has taken that long to adequately describe the available germplasm and its agronomic variation and to confirm that a number of additional species remain to be fully exploited by tropical pasture science. Starting in 1967, CSIRO began a detailed study of the genus *Stylosanthes* at Townsville based on the proved potential of *S. humilis* and *S. guianensis*. CIAT started collecting and evaluating in 1972, with the aim of developing cultivars adapted to acid soils in the humid tropics.

The first phase of this work emphasized collecting germplasm and consisted of a series of missions aimed at broadening the genetic base of the genus in cultivation. The material was characterized and evaluated through a series of national and international cooperative testing programmes, over a range of tropical environments (Schultze-Kraft *et al.*, 1984). The results of this work led to the second phase of the programme, when individual species and ecotypes were developed to the point of domestication. They were adapted to a wider range of environments than *S. humilis* and *S. guianensis* and greatly extended the boundaries of feasible pasture improvement. Such new species as *S. capitata* (adapted to the low-fertility acid soils of Brazil, Colombia and Venezuela), *S. hamata* (which grows well on a range of soils in the semiarid tropics) and *S. scabra* (which is particularly resistant to disease) became well known throughout the tropics. As researchers and farmers gained further experience with this material, and as limitations became apparent (e.g. disease susceptibility, lack of salt tolerance, low nutritive value), the third phase of the programme began. This entailed returning to collect from the original areas of succesful introduction, i.e. northeastern Brazil for *S. scabra* and northwestern Venezuela for *S. hamata*. In the latter case, detailed exploration has occurred in the upland areas of the Lara and Falcon searching (successfully) for ecotypes that are as drought-tolerant as the existing cultivar but more cold-tolerant. New variation continues to emerge in most species of agronomic importance (Edye, 1987). From an initial 167 accessions in the mid-1960s, over 8000 accessions have been collected by various organizations so far and are at various stages of characterization and evaluation.

For valuable germplasm to reach the user (i.e. the evaluator and ultimately the farmer) as quickly as possible, data on the collecting site are required. Some evaluators argue that only the most detailed site data should be recorded and that approximations may ultimately be misleading. This school of thought advocates the use by the collector of very detailed environmental descriptors, which are deemed to be indispensable for the accurate selection of ecotypes of forage plants adapted to particular conditions. Others disagree. While recognizing their responsibility for recording site information, many collectors claim that time and other logistical constraints will preclude the noting of all but the most basic site descriptors. Certainly, it is important that what ecological data are gathered be recorded in such a way that they can be used for comparative purposes. Most collectors make some observations on the general area of collection, even if only at the most basic level, e.g. 'forest edge', 'desert grassland' or 'swamp'. Others, perhaps with a greater knowledge of the land, may use such terms as '*Cenchrus–Chrysopogon* grassland', 'xerophilous open woodland' or '*Acacia* savannah'. Where very well-known communities are involved, it is possible to convey a great deal of information by using such local descriptive terms as 'caatinga' (Brazil), 'kunai' (Papua New Guinea) or 'miombo' (Zimbabwe).

It has rarely proved to be feasible in practice to describe in detail the overall community, or conduct a detailed analysis of the vegetation, during the course of collecting. However, associated species are important in determining the ability of the plant to compete successfully in a given environment and are useful guides to the possible companion species in an improved pasture. For example, *Pennisetum clandestinum* and *Trifolium semipilosum* occur together in the highlands of Kenya, and *Neonotonia wighti* and *Panicum maximum* in Zimbabwe. Both combinations have been used in improved pastures in other countries with broadly similar environments.

A description of the climate at the collection site is an important part of the environmental data required for evaluation. Data from the nearest metereological stations need to be interpolated or extrapolated to get an estimate of climatic variables at the site of collecting. This will prove difficult in areas such as steep mountainous terrain, where conditions can vary enormously over short distances. However, in extensive areas with little surface relief (e.g. the Sahelian zone or much of the Amazon Basin), annual rainfall and temperature regimes at any given site can be readily approximated. In such cases estimates with an error of ±25 mm in the annual rainfall total are quite acceptable and have proved invaluable to evaluators.

Of equal importance to basic climatic data is the description of the soil at the collecting site. Unfortunately, most tropical forage collectors have little training in soil science and even such simple descriptions as 'deep sands' or 'cracking clay' are rarely recorded. In an examination of passport data accompanying tropical forage species collected by IBPGR-funded missions, less than 20% of samples had any climatic data (usually annual rainfall) and less than 10% had edaphic data (usually drainage). Ideally, an indication of the soil type and its surface texture should be obtained at the same time as the collector is testing for soil pH. In addition, some indication of the depth to any clay layer is desirable and is readily obtained with a small auger. The nutritional status of the soil is important but relatively difficult to measure without taking samples for laboratory analysis. When this is possible, it should be encouraged as it is extremely useful in evaluation.

Until recently, most tropical pasture collectors were also involved in evaluation of the material they collected. If not engaged in the hands-on initial characterization stage, then at least they were fully aware of where, and for what purpose, the germplasm would be evaluated. As more organizations become involved in plant germplasm collecting, there is a danger of collecting becoming somewhat divorced from use. Species of little value are collected simply 'because they are there' and valuable samples languish in obscurity in gene banks. One possible solution is to link researchers interested in all aspects of tropical pasture germplasm in a network, through which they can communicate their interests and coordinate their activities. An example is the Dryland Pasture and Forage Legume Network, sponsored jointly by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Plant Genetic Resources Institute (IPGRI). Various national and international organizations are currently investigating the possibility of a similar structure for tropical forages.

In summary, the successful collecting of tropical forage plants has been characterized by thorough planning, in particular the exploration of the herbarium prior to the landscape. Tropical forage collectors are usually covering new ground both figuratively and literally. They need skills in a wide variety of different fields, from taxonomy to climatology. They also need common sense, however. Wild forage plants are often difficult to find and identify, often few in number at a given site, often morphologically very variable and rarely well studied. The sampling procedures required will depend more on what is available than on sophisticated strategies based on the population structure of the target species. A large number of tropical forage accessions have been accumulated since planned exploration began. However, the fact remains that there are still numerous species and ecotypes that are known about but which remain inadequately collected or not collected at all. Some regions have yet to be explored even in a general way and most habitats need to be examined in further detail. Many useful plants are still to be discovered, if the evidence of the last 30 years is any indication, but collectors are all too often just ahead of the land clearers, and in many cases a long way behind.

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