Surveying *Mangifera* in the tropical rain forests of southeast Asia

31

J.M. Bompard
Laboratoire de Botanique, Institut Botanique, Université des Sciences et Techniques du Languedoc, 163 rue Auguste Broussonet, 34000 Montpellier, France.

Introduction

To date, genetic improvement of the Indian mango (*Mangifera indica*), a tropical fruit of major importance, has depended on the exploitation of intraspecific variation only. Yet there are some 60 species in the genus, displaying considerable diversity, especially in fruit characters, and occurring in a wide range of environmental conditions and over a large geographic area. Tapping this rich gene pool can be expected to lead to significant progress in mango breeding (Kostermans and Bompard, 1989). However, deforestation is occurring at alarming rates in many areas within the range of the genus, which extends from India to Melanesia and Micronesia. There is thus general agreement on the need for active measures to ensure conservation of the gene pool.

A sound taxonomic base is a prerequisite for any such conservation effort and for the informed use of germplasm. Accurate identification of vouchers and of living material in collections and in the field is the basis of genetic resources work, in *Mangifera* no less than in other groups. Unfortunately, existing taxonomic treatments of the genus are not completely satisfactory (Mukherjee, 1949, 1985; Hou, 1978; Kochummen, 1989). They are based on inadequate herbarium material, the flowers or fruits of several species being unknown. When not entirely lacking, descriptions of fruit characters are generally poor since they are often based on the study of dried herbarium material only. The determination of sterile material is very difficult due to extensive intraspecific variation in vegetative characters, showing intergrading between species in many cases.

Mangifera is not alone in this. The taxonomic treatments of many other fleshy tropical fruits (e.g. the genera *Baccaurea*, *Eugenia* and *Garcinia*) need to be updated or revised. Intensive collecting in poorly

explored areas inevitably brings out new material and hence new data on the distribution and range of variation of these taxa.

The IBPGR/IUCN/WWF project

In view of the lack of adequate taxonomic knowledge and of probably rapid genetic erosion of the gene pool, the World Conservation Union (IUCN), World Wide Fund for Nature (WWF) and International Board for Plant Genetic Resources (IBPGR) agreed in 1984 to initiate field surveys of *Mangifera* with emphasis on Borneo and Peninsular Malaysia, the probable areas of maximum diversity. The main objectives of the project were as follows:

- to draw up an accurate inventory of the *Mangifera* species in the region and their intraspecific variation;
- to compile ecological and agronomic data on each species (distribution, habitat, morphological and fruit characteristics, actual and potential economic value);
- to assess the conservation status of each species, and any threats of genetic erosion;
- to explore the possibilities for *in situ* conservation, identify gaps in the present system of protected areas and recommend measures to ensure the long-term survival of this germplasm.

The emphasis of the project was on collecting herbarium specimens of the flowering and fruiting material necessary to solve taxonomic problems and clarify the taxonomic treatment of the genus. When possible, living material was also to be collected and established in field collections. Mango seeds are recalcitrant, which means that drying and long-term storage at low temperatures are not yet a viable conservation option. At best, the seeds of *M. indica* can be stored for about 100 days (Chin and Roberts, 1980). Conservation thus needs to focus on the establishment of field collections and *in situ* reserves.

Following a preliminary exploratory survey conducted in 1985 in Kalimantan, intensive surveys were carried out in 1986–88 in Kalimantan in cooperation with the Indonesian Institute of Science and the Indonesian Commission on Germplasm and in West Malaysia in cooperation with the Forest Research Institute of Malaysia (Saw, 1987; Bompard, 1988). Surveys were also carried out in Sabah by the Sandakan Forest Research Centre (Lee Ying Fah, 1987) and in cooperation with the Sabah Agriculture Department.

Constraints on collecting

The constraints imposed on collecting by difficult field conditions in inaccessible areas are well known and do not need to be reviewed here,

but those inherent to the target species themselves do repay consideration. One such problem is the fact that target trees occur at very low densities in dense forest. Most wild *Mangifera* species found in Borneo and the Malay Peninsula are canopy or emergent trees of the tropical lowland rain forest. They are as a rule large trees, up to 50 m in height. Several species are exploited for their timber. A few species – e.g. *M. gedebe*, *M. griffithii* and *M. parvifolia* (syn. *M. havilandii*) – are gregarious in certain types of swamp forest (with densities of 20 trees per hectare). A couple of species occur in mountain forests between 1000 and 1800 m above sea level. The majority, however, occur as scattered individuals at very low densities in dry lowland forest, where the genus is represented by an average of one to three trees (>40 cm in diameter) per 10 ha. This kind of dispersion clearly means that finding trees is difficult and time-consuming. It also means that defining the population from which one is sampling is almost impossible.

Mangifera species (like those of many other genera in the West Malesian floristic region) flower and fruit very irregularly. Even if a tree is located, therefore, the chances are overwhelming that it will not be in flower or fruit. Mast fruiting at intervals of two to eight years is the dominant pattern. In mast years the ground beneath the trees can be covered with fruits, whose strong smell attracts many animals. This mast flowering can be widespread or restricted to certain areas. The rate of flowering of a few species (e.g. *M. lagenifera* and perhaps also *M. subsessilifolia*) is only once in five to eight years. So far, it has not been possible to collect fertile material of *M. subsessilifolia* despite monitoring of marked trees for four years. Isolated flowering may occur at shorter intervals and is generally followed by poor fruiting. Most of the *Mangifera* trees of wild origin growing in village areas (i.e. in a more open environment) tend to flower more regularly, though they have a flowering habit basically similar to that of trees growing wild in the surrounding forests. Two species (*M. rufocostata* and *M. swintonioides*) have the peculiarity of flowering and fruiting outside the main season.

These constraints highlight the need for intensive preparation, neglecting none of the possible sources of information, and for explorative surveys before undertaking collecting missions.

The preparation and planning of collecting missions

Herbarium data

Mangifera collections were studied in the major world herbaria and in several local herbaria. Herbarium data are valuable first-hand information not generally available in published works, continuously augmented by the addition of newly collected material. Data on distribution, habitat, reproductive phenology and vernacular names were systematically entered into a computer database from more than 2500 herbarium labels.

Herbarium data can be very useful in determining the optimum time for collecting. Unfortunately, the herbarium study was able to provide only limited information on the reproductive phenology of *Mangifera* species. Generally, fertile specimens from a given region from which data on flowering or fruiting time could be gathered were not numerous enough to convey an adequate idea of the optimal date for collecting in that region. In the best cases, they narrowed down the choice to a period of several months.

A thorough review of herbarium collections can also help in becoming familiar with the range of morphological variation present in the target taxa and it is thus a good idea that such a study be carried out by the prospective collectors themselves. Such knowledge is vital if one is to be able to check determinations and eventually assess deficiencies in the current state of taxonomic knowledge, as set out in Floras and monographs. Visiting collections of living material in botanic gardens is also helpful in this connection. A few cases of ecotypic variation could be identified during the course of the herbarium survey. For instance, *M. griffithii* growing in markedly different habitats (dry land or freshwater swamp forests) showed differences in leaf shape and texture.

Data from the literature

A broad knowledge of the proposed survey areas was gained by gathering together ecogeographic information on the target regions from the relevant literature and maps on geology, soils, climate and vegetation. These were used to identify ecological units and areas of particularly high environmental diversity. Information on human diversity, which can be as important a determinant of *Mangifera* diversity as the physical environment, was gathered from the specialized ethnographic literature. These works often contain such data as the vernacular names and local uses of plants.

Data on the occurrence of target species were collated from forest inventories and accounts of previous collecting. The inventories compiled by forestry services are usually of limited use in this context as *Mangifera* species are generally merged together under their generic local timber trade name. More information was found in inventories of forest research plots. Though these are scarce, the records are generally substantiated by herbarium specimens, allowing the verification of determinations and the collecting of additional data from herbarium labels. Permanent forest research plots make it easy to localize particular trees, which are mapped and numbered. They also contribute to a better knowledge of the reproductive phenology of species, as flowering or fruiting times are regularly recorded.

Identification of targets

Despite the gaps in the herbarium and literature data, it was possible to recognize specific regions, areas and taxa as being high priorities for *Mangifera* collecting. Two priority regions were identified. One was

Borneo, especially its Indonesian part (Kalimantan), which was insufficiently explored, and the other was West Malaysia (Peninsular Malaysia), clearly a major centre of diversity. Within these target regions, areas fulfilling the following conditions were selected for detailed study:

- areas likely to have particularly high species diversity or including distinctive ecological conditions (e.g. freshwater swamp forests);
- existing or proposed protected areas (national parks, nature reserves);
- areas insufficiently known from previous collections;
- sites threatened with imminent habitat destruction (e.g. limestone outcrops being exploited as quarries).

The collecting priority accorded to each taxon (whether groups of species, species or infraspecific taxa) must also be clearly defined. Not all the *Mangifera* species required the same intensity of collecting. Moreover, due to practical constraints, it was not always possible to devote the same effort to collecting every representative of the gene pool. The collector may have to decide, for instance, between devoting a few days to assessing the intraspecific variation in a couple of species seen fruiting in local forest gardens along a certain river and going further up-river to explore a forest where a rare wild mango, also fruiting at that time, is reported by local people. A clear understanding of priorities helped in making the right decision when a choice between several alternatives presented itself in the field.

High priority was given to finding insufficiently known taxa, notably little-collected species and those known only from poor material. For instance, the project succeeded in relocating *M. longipetiolata*, a species described more than a century ago from Larut Hill, in Perak, West Malaysia. Fortunately, the area is still forested, as it belongs to the Forest Reserve network of Malaysia. *M. whitmorei*, however, only collected once (in 1971), could not be found again. The original collecting site in the Upper Perak, West Malaysia, has been flooded by the Temenggor Dam and the species was not found in the forest remaining in the vicinity, which is being logged.

In such cases, the objectives are clear in terms both of taxa and of areas, but more generally an area was explored simply on the suspicion of the possible presence of certain species, for example based on information on habitat preferences. Very often during the survey work sites were visited based on no more than a guess as to what species a local informant might be referring to. Sometimes it happened that the guess was correct. It was often more exciting, however, when the guess was wrong. The 'odd wild mango' described by local people might well turn out to be a new species or a new record for the region, or, indeed, not a *Mangifera* at all. To finally arrive at the locality in question, after a few hours' walk, only to learn that the rare tree had been chopped down a few weeks earlier was, sadly, a not uncommon occurrence.

Two-phase collecting

Planning was of necessity usually a two-phase process, in which the determination of collecting areas, itinerary, routes and timing, based on the herbarium and literature work described above, was modified on the spot to take account of the actual situation in the field. The most appropriate collecting itinerary, for example, could often be definitively selected only on the spot on the basis of information that was only available locally and had to be up to date, such as the condition of roads or rivers at that time.

As for determining the optimum time for collection, it has already been mentioned that a period of several months could usually be approximately defined. Peak flowering over most of Kalimantan, for example, occurs from September to December, before the onset of the rainy season, or after a dry spell during the wet season (north of the Equator, in January–February). However, the exact period of flowering and fruiting and its intensity vary greatly from year to year and could not be predicted for a given area unless precise information was provided by local informants.

In some cases, both flowering and fruiting material of the same tree are needed to solve taxonomic problems. A preliminary survey mission during the flowering season can help to predict the ideal time for a second visit during fruiting. Following this procedure, it was possible to collect the fruits of 16 *Mangifera* species during a one-month collecting mission, from trees marked during a preliminary survey. By chance, this collecting trip coincided with a period of mast fruiting. It was even occasionally possible to ask people in the field to monitor certain mango trees and send back information about their phenology or even collect material.

When conventional sources of information proved to be inadequate, a roundabout approach sometimes paid off. For instance, it would have been useless to ask desk officers in forestry or agriculture departments in towns whether wild mango species were likely to be available on the local markets in the hinterland at that time. The same people, however, would be able to say whether the durian season had started and whether that year it was a poor or a good one, the durian (*Durio zibethinus*) being a very popular fruit in southeast Asia. This is a useful clue to the intensity of the fruiting season in a particular area for other forest fruits, including several mango species. People who have just arrived from up-river areas and middlemen trading local fruits were found to be important strategic informants, able to provide information which often proved to be very useful in determining which one of the preselected collecting routes it was best to concentrate on.

The role of indigenous knowledge

In view of the constraints, collecting adequate specimens of trees like *Mangifera* may sound like mostly a matter of luck. If it is actually not as bad as that, it is thanks to the knowledge local people possess of the forest and its products. Traditionally, shifting cultivators do not cut down useful species such as fruit trees or bee-trees when clearing the land, so that most wild mangoes can be found in the secondary forest surrounding settlements. Local people also plant seeds or seedlings collected in the forest in gardens near their homes. A high diversity of mango relatives in old forest gardens may thus partly reflect the diversity of edible wild mangoes occurring in the surrounding forest.

In view of this, surveys were first made in old village forest gardens and secondary forests, collecting as much information as possible from local people along the way. Valuable information was gained by exploring local markets in remote areas, for example. By questioning the stall-keepers, it was possible to trace trees that needed to be collected. In Borneo, no less than 16 species can be bought in local markets, though several are for sale only very occasionally or in limited quantities. The next step was to move on to primary forests, especially protected forest areas. In tall primary forest the crown of mango trees can rarely be seen and the trees must be detected by observing the forest floor closely for fallen leaves, seedlings or rotten seeds and watching for trunk and bark features. Here also, the task of hunting for mangoes can be made somewhat easier by the help of local people. The best informants were local people engaged in logging, hunting or collecting forest products (such as rattan, eaglewood and birds' nests) and such hunter-gatherer groups as the Orang Asli aborigines living in Taman Negara National Park in West Malaysia.

An important facet of indigenous knowledge is vernacular names. These can be extremely helpful. In the case of *Mangifera*, the degree of precision of a name (i.e. whether it refers to a group of species, a single species or a variety) can be a measure of the importance of the trees, as a source of food or in folklore or myth. A vernacular name can also suggest exotic origin (e.g. corrupted names borrowed from a different language or the designation 'Mango from the coast') or confirm local origin (e.g. 'Mango from the forest'). A checklist of the vernacular names collected in a particular area can provide some indication of the diversity of indigenous and introduced mango types known to occur there, though it should never be considered complete.

It is important, however, to be aware of the limitations of vernacular names. A given name will tend to be valid only within a specific area. Also, although local people possess a vast knowledge of the forest and its products, this is not equally shared by the members of a community. Names need to be cross-checked with several reliable informants, especially elderly people. Totally fanciful names (even insults) have been carefully noted down by collectors ignorant of the language and customs

of the local people. It is notoriously difficult to agree on the transcription of local names and easy for errors and disagreements in pronunciation and spelling to accumulate in published lists. A basic knowledge of the languages and ethnography of the region is necessary to avoid these and other dangers.

Collecting and documenting germplasm

Having located a tree of a target taxon, herbarium material and, if possible, living material for *ex situ* conservation were collected. The latter consisted mainly of seeds, which can be kept for up to several weeks if cleaned. Whenever feasible, seed collections were sent by special delivery services from Kalimantan to Java. Otherwise, the collecting itinerary was so devised as to include visits to marked trees on the way back, to reduce the length of time living material spent in transit. In the very few cases when living material was especially desired but fruits were not available, budwood was collected. Cuttings were carefully cleaned and wax placed on the cut ends. They were wrapped in wet newspaper and stored in plastic bags kept open for ventilation. Varieties of *M. casturi* thus collected were successfully grafted on *M. indica* cv. Madu at the Kraton collection near Malang in East Java.

Following the requirements of the Indonesian National Commission on Germplasm, all living material was established at Kraton. Seeds were also distributed to the Bogor Botanical Garden, the Cipaku Horticulture Station near Bogor and the National Centre for Research, Science and Technology at Serpong near Jakarta, which keeps a garden of rare plants.

It is essential that collections, whether of herbarium material or germplasm, be adequately documented. The effort of locating rare trees in deep forest at the right moment in their irregular reproductive cycle will largely be wasted if precise field records are not kept. It is equally important for the information to be made widely available. A reference collection of the material and associated data collected during the course of the *Mangifera* surveys has been deposited in the national herbarium involved and duplicates sent to major world herbaria.

Among the information on each sample that was collected in the survey work were:

- geographic data on the locality precise enough to make it possible for future collectors to locate the same tree again;
- notes on the site, including vegetation type, habitat and target species frequency;
- morphological data, in particular detailed descriptions of flowers and fruits, especially features which disappear or change on drying;
- vernacular names and local uses, always with an indication of the language or dialect and the area of validity;

- information on the degree of genetic erosion and actual or potential threats to the habitat.

Floristic information was also gathered in each collecting area, in particular regarding useful hardwood species, other wild crop relatives and so on. This can be extremely useful in providing additional justification for the *in situ* conservation of a particular site.

Results and prospects

Herbarium specimens collected during the surveys have made a significant contribution to taxonomic knowledge of *Mangifera*, helping in the preparation of a monograph (Kostermans and Bompard, 1993). It is worth repeating that a sound taxonomic base, such as can only be provided by this kind of publication, is absolutely essential for the assessment of future use possibilities and for proposing appropriate conservation measures.

The Malay Peninsula, Borneo and Sumatra represent the areas of highest *Mangifera* diversity. The selection of Borneo as a target region proved to be fully justified as more than 20 species, including several new ones, were found there, as against the 11 recorded in the literature before the project. Out of the 30 or so species currently recorded in Borneo and the Malay Peninsula, 26 species (plus hybrids and varieties) were collected during the surveys. Herbarium specimens of 204 numbers were made, about one third from truly wild trees, the rest mainly from semicultivated trees of wild origin. Of the trees collected, 16% were found in flower, 25% with mature fruits, 5% with immature fruits and 54% with neither flowers nor fruits. As regards trees of primary forest, nearly 90% had neither flowers nor fruits at the time of collecting, highlighting again the special problems posed by the reproductive phenology of these species.

Wild species, semicultivated species on the path to domestication and primitive cultivars found in Borneo form an outstandingly rich gene pool which is unique to this region. An important part of such genetic diversity can be explained by the great ethnic diversity of the indigenous inhabitants. Several species, for instance, are 'semicultivated' in Borneo, but wild in West Malaysia. The cultivation of local races (and even species) is often very restricted. Some of these species and forms have direct potential economic value. Species with a peculiar taste might have potential for making juices and flavouring yoghurt, for example. Wild mangoes also offer great possibilities in mango breeding and improvement. The results of these surveys show that wild *Mangifera* species exhibit several desirable characters, such as: resistance to anthracnose, the ability to grow in inundated areas, the ability to grow at high altitude, the absence of fibre, high fruit setting rate and out-of-season fruiting. Wild mangoes also offer great possibilities in mango breeding and improvement (Bompard, 1993).

There is no doubt that this wealth of genetic resources is under threat. Besides the high rate of destruction of lowland forests (the major habitat of *Mangifera* species), there is a high degree of genetic erosion among mangoes occurring in man-made landscapes. Even in remote areas, old mango trees are being cut down and only a few species (*M. caesia, M. foetida, M. odorata* and *M. pajang*) are regularly replaced.

How is *Mangifera* germplasm in southeast Asia to be conserved? Long-term seed storage is not feasible at present, so *ex situ* conservation would have to involve living collections in field genebanks. There are very few such collections of native fruit trees in Borneo, the most important one that of the Sabah Department of Agriculture at Tenom (Lamb, 1987). There is a special need to establish representative collections of the variation in the species closely related to the Indian mango (e.g. *M. laurina* and *M. pentandra*) and of the primitive cultivars of species of potential economic importance (e.g. *M. casturi*). This material will then be more easily accessible to potential users. However, it might be that wild species established in field gene banks do not fruit for very long periods (much longer than in the wild) even when the edaphic and climatic conditions are more or less similar to those of their original homes. For instance, a mature tree of *M. macrocarpa* flowered only twice and fruited only once in 20 years at the Ulu Dusun Agricultural Station in Sabah and a similar situation is recorded for the same species in the Bogor Botanical Garden. It is also unrealistic to think that the entire range of existing diversity of semiwild and cultivated forms of mangoes found in Borneo can be adequately conserved in traditional living collections.

In situ conservation is thus perhaps a better option. The project has initiated inventories of *Mangifera* species occurring in several protected areas and the conservation status of each species has been assessed. The areas of maximum species diversity and high intraspecific diversity for different species have also been identified in a preliminary way. The bulk of Malesian *Mangifera* species, at least 21 out of 28 native species found in West Malaysia and/or Borneo, are present in protected areas located in these two regions. It should be noted, however, that not all the protected areas have similar legal status or comparable conservation importance (IUCN and UNEP, 1986). *In situ* conservation of wild mangoes requires effective protection of large areas of undisturbed forests. Selecting candidate genetic reserves is difficult due to a general lack of basic floristic data. Data on the occurrence of wild mangoes should ideally be considered together with those on other wild crop relatives (e.g. other important fruit trees, such as *Artocarpus, Dimocarpus, Durio, Garcinia* and *Nephelium*).

The results of the mango project demonstrate that a specialist group focusing on collecting a single-crop gene pool is fully justified, but *in situ* conservation measures will be easier to justify and better perceived by conservation planners once data for several groups of crop relatives are available. It is hoped that the results of the Inventory of Plant

Resources in Kalimantan, a project of the Arnold Arboretum, will contribute to assembling such a comprehensive picture. Considering the wealth of Bornean fruit tree diversity and the high degree of genetic erosion, an action plan for the conservation of Borneo fruit trees genetic resources bringing together all the concerned people – users, conservationists, botanists and foresters – is probably the best way forward.

Much collecting remains to be done. In-depth preparation and good planning are prerequisites for success, though chance and intuition, based on acquired field experience, surely play a part. But it is perhaps only strong motivation that in the end allows the collector to overcome the many difficulties, both practical and scientific, which inevitably arise in the field. It is in many cases a race against time. Plant collectors know that there is always a way to find what they are looking for. Provided that it is still there to be found.

References

Bompard, J.M. (1988) *Wild* Mangifera *Species in Kalimantan (Indonesia) and in Malaysia.* Final report on the 1986–1988 collecting missions. Report to IUCN/WWF/IBPGR.

Bompard, J.M. (1993) The genus *Mangifera* rediscovered: the potential contribution of wild species to mango cultivation. *Acta Horticulturae* 341:69–77.

Chin, H.F. and E.H. Roberts (eds) (1980) *Recalcitrant Crop Seeds.* Tropical Press Sdn. Bhd., Kuala Lumpur.

Hou, D.H. (1978) Anacardiaceae. 4. *Mangifera.* In: van Steenis, C.G.G.J. (ed.) *Flora Malesiana* 1(8):423–440.

IUCN and UNEP (1986) *Review of the Protected Areas System in the Indo-Malayan Realm.* IUCN, Gland.

Kochummen, K.M. (1989) Anacardiaceae. In: Ng, F.S.P. (ed.) *Tree Flora of Malaya. A Manual for Foresters,* 4:9–57. Longman, Petaling Jaya, Malaysia.

Kostermans, A.J.G.H. and J.M. Bompard (1989) Mangoes. In: Siemonsma, J.S. and N. Wulijarni-Soedjipto (eds) *Plant Resources of South-East Asia.* Proceedings of the First PROSEA International Symposium. 22–25 May 1989. Jakarta, Indonesia. PUDOC, Wageningen.

Kostermans, A.J.G.H. and J.M. Bompard (1993) *The Mangoes. Their Botany, Nomenclature, Horticulture and Utilization.* Academic Press, London.

Lamb, A. (1987) The potential of some wild and semi-wild fruit trees in Sabah and the progress made by the Department of Agriculture, Sabah in establishing a germplasm pool. Paper to a Forest Research Institute of Malaysia meeting, Kepong, Malaysia.

Lee Ying Fah (1987) *A Preliminary Survey of* Mangifera *Species in Sabah.* Report to WWF-Malaysia.

Mukherjee, S.K. (1949) A monograph of the genus *Mangifera* L. *Lloydia* 12:73–136.

Mukherjee, S.K. (1985) Mangifera *L.* Systematic and Ecogeographic Studies on Crop Genepools 1. IBPGR, Rome.

Saw, L.G. (1987) *Conservation of the Mango and its Wild Relatives in Peninsular Malaysia.* Report to WWF-Malaysia.