CHAPTER 2

Collection

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One of the most important differences between tropical and temperate forests is the high degree of species diversity in tropical forests. While a tract of temperate forest might contain 25 tree species, a tropical forest of similar size might easily support 10 times that number. Indeed, there are probably more than 50,000 arborescent species in the Tropics. As byproducts of this vast biological diversity and a broad range of climate, economic conditions, and political systems, tropical tree nurseries and seed-collecting organizations vary enormously in structure and in methods employed to collect and process seeds. These nurseries and organizations range from the most sophisticated and mechanized operations to tiny nurseries that use only hand labor and locally manufactured materials. All use valid and necessary means to solve the unique problems of each local situation.

Seed collection and processing operations are molded by the objectives driving them. Industrial objectives, such as supplying raw material to a productive mill or satisfying the demands of an export contract, require the production of abundant quantities of relatively high-quality seeds of one or a very small number of species. Usually great care is taken to select or produce seeds from highly productive genotypes. Most of these seed-collection organizations have generous budgets and a high degree of mechanization.

Seed suppliers that produce seed for sale both within their own countries and for export are required to produce the highest quality product possible. It must contain little debris and be free of insects and weed seeds. Superior genotypes bring premium prices, but all lots must be forest-run (representing the average for wild trees) or collected from trees of selected phenotypes. There is constant pressure to offer as many species as possible, but costs tend to escalate with the number of species maintained in collections. These operations may employ one to many people, have varying degrees of mechanization, and be government affiliated or private.

The most common objective of seed collection in the Tropics is to support local tree nurseries. These nurseries are the principal source of tree seedlings for homeowners, cities, farmers, and conservation and forest management organizations who use the seedlings for ornamental, agricultural, agroforestry, conservation, and silvicultural purposes. They typically maintain a relatively large inventory of the few species that are in continual demand (all of which are reliable seed producers) and a group of other species that changes as seed collection opportunities present themselves. Seeds are usually collected by nursery employees or purchased from local seasonal collectors. Seeds are rarely stored for more than 1 year. Seed quality and handling are highly variable. Because wages are low in most of the Tropics and in some places the objective of providing employment supersedes that of producing seedlings, labor is often substituted for equipment or improvements requiring capital investment. Unfortunately, product quality and efficiency may decrease.

Collection and processing problems are species-driven. Hence, the greater the number of species handled, the greater the number of problems that must be solved. Unfortunately, some species are planted because their seed collection and management are easy, not because they are the best species available to meet the need. Many superb species are rarely or never planted because their seeds are difficult to collect or use. As experience in seed collection and management increases, many exciting species will be added to plantation inventories. Increasing the number of species we are able to successfully reproduce by seed will facilitate the difficult task of rehabilitating damaged ecosystems. This chapter reviews some of the challenges to seed collection and processing in the Tropics and the approaches to meeting these challenges.

SEED COLLECTION

GENERAL METHODS

It is important to remember that fruit characteristics evolved to facilitate a seed dispersal strategy. Often a seed collection, extraction, or germination technique has simply mimicked the natural process.

From the Ground

The mainstay of seed collection is and will remain the picking up of the fruits or their seeds from the ground after they fall. This method is especially convenient for species with large or conspicuous fruits or seeds such as *Melia azedarach* L., *Ormosia krugii* Urban, and *Terminalia catappa* L. Protective pods enable collection of fruits of such species as *Crescentia cajute* L., *Hymenaea courbaril* L., *Pterocarpus macrocarpus* Kurz, and *Senna spectabilis* (DC.) Irwin and Barneby, weeks to months after fruit-fall. Even the seeds or fruits of relatively small-seeded species, such as *Bucida buceras* L. and *Petitia domingensis* Jacq., can be collected from the ground if it is bare or paved, or if a tarp is placed under the tree just before fruit-fall. In those circumstances, vacuuming or sweeping can sometimes speed the collection process.

From the Tree

Another common means of collecting fruits and seeds is picking them from the trees. It is faster in many cases than collecting from the ground and it keeps the seeds cleaner. In addition, the seeds of many species are too small to pick up from the ground, and others are dispersed widely or consumed by animals and insects before they fall. Short trees may allow hand picking. Production can be accelerated by flailing into a basket attached to a picker's waist.

Picking must occur between physiological ripening (timed so the fruits will ripen in storage) and release by the tree or consumption by predators or dispersers. Ripeness is usually indicated by a color change of the fruit from some shade of green to an indicator color such as brown or red. In some cases, animal predation indicates ripeness. The sight of cockatoos feeding on the seeds indicates that *Agathis* seeds are ripe (Whitmore 1977). The seeds of many species, such as *Albizia lebbeck* (Kunth) Harms and *Melia azedarach* L., remain in their fruits on the trees for weeks or months, greatly facilitating collection. Many of the eucalypts carry large quantities of fruits for extended periods that open quickly after fires (Cremer and others 1978) These fruits will also open after the clipped twigs dry. Species with serrotinous cones, such as *Pinus patula* Schiede & Deppe, produce cones that remain on the tree with viable seeds 1, 2, or more years after ripening (Wormald 1975).

SPECIAL CHALLENGES

Tall Trees

Most species are too tall for hand picking. Pole pruners provide a convenient and inexpensive way to collect fruits from 2 m to about 9 m above the ground. Stepladders and easily portable, straight or extension ladders up to 7 m are also used. Fruits or seeds that shatter or detach easily, or seeds that are ejected from their fruits, can be collected by placing a tarp under the tree and flailing the tree with a long pole. In similar approaches, trees are shaken by hand (if small), by mechanical shaker, or by attaching a chain or rope to the trunk as high as convenient and to a vehicle or another tree, then jumping up and down on the chain or rope or pulling back and forth with a vehicle. A particular benefit of collecting seeds by shaking is that for species such as *Cordia alliodora* (Ruiz & Pavon) Oken, in which all the fruits or seeds do not mature at the same time, shaking releases the mature fruits while the immature fruits remain on the tree (Greaves and McCarter 1990).

When short-statured species, such as *Acasia farnesiana* (L.) Willd., *Hibiscus tiliaceus* L., and *Moringa oleifera* Lam., and precociously flowering species such as *Spathodea campanulata* Beauv., invade cleared areas, they are short enough to pick by hand or pole pruner. Trees planted in open-grown situations sometimes grow low enough for easy harvest. Open-grown *Swietenia* spp. will usually bear many of its fruits within 9 m of the ground but does not do so in closed forests. Many species will continue to bear fruits after pruning to a low crown. Fruit trees, including *Mangifera indica* L. and *Citrus* spp., are routinely managed this way. Crown-shaping trials with many tropical forest species should be conducted.

The seeds of timber trees in natural forests are often borne near the tops of very tall trees. Traditionally, these seeds are collected from trees felled by logging operations. The method is excellent, if available. However, felling can shatter seed clusters and produce enough slash to hinder fruit retrieval. In some areas, trees have been destructively felled to obtain the seeds (Britwum 1973). Generally considered unacceptable ecologically and economically, this method may be beneficial if the seed trees are scheduled for removal to improve the stand.

The challenge of collecting seed from tall trees has inspired a number of approaches. Small quantities of seed, usually intended for breeding or provenance trials, have been collected by shooting down limbs with rifles or shotguns. Slingshot pellets and thrown sticks have been used to shatter small quantities of seed. Arrows have been used to draw lines over limbs to cut down or shake down small quantities of seed. Traditionally, local climbers were hired to ascend the trees and pick the desired seed in quantity with little or no safety equipment. Any conscientious collector would now require the use of safety harnesses and belts, safety lines, and helmets. Tree-climbing spurs, tree bicycles, tethered sectional ladders, and other climbing aids can greatly accelerate an ascent up the tree bole. Once up the tree, a collector often uses a pruning pole to clip fruits on the ends of limbs or to saw off fruit-bearing limbs. Finally, seed collectors with generous budgets use high-lift buckets on hard and nearly level ground to collect fruits from tall trees.

Widely Scattered Seed Trees

In tropical moist forests, seed trees of many species grow more than 1 km apart. Seed-producing adults of heavily exploited and rare species can often be very difficult to find. Random searches can be incredibly time consuming. Traditionally, seed collectors maintain a mental inventory of known seed trees or potential seed trees they have sighted during excursions through the forest over the years. Although it takes many years to accumulate this degree of experience, the system works well as long as these inventories are handed down to succeeding generations of collectors. The alternative is to maintain a written inventory of potential seed trees of at least the critical species along with maps of their locations. Modern technology can add efficiency and accuracy to this time-consuming process through the use of computer data bases and global positioning satellite (GPS) technology.

Genetic Impurity

A number of species hybridize freely with members of the same genus or varieties within the same species to produce undesirable or unpredictable offspring. The *Swietenia*s have hybridized freely in Puerto Rico and the seeds of *Eucalyptus robusta* Sm., obtained from Brazil many years ago, introduced many hybrids that were generally inferior to the pure species. The timber tree *Hibiscus elatus* Sw. has been reported to hybridize with the shrubby *Hibiscus pernambucensis* Arruda in Jamaica (Adams 1971). In the case of *Swietenia*, the hybrid seedlings can usually be separated from the parent species by leaf size. With *E. robusta*, sorting is impossible. The problem is solved by collecting from well-identified and isolated seed trees.

Unknown or Unpredictable Fruiting Seasons

In that portion of the Tropics with a strong wet-dry seasonal cycle, almost all species flower and fruit in certain well-defined seasons. Phenological studies can document these seasons and seed collection can be planned accordingly. However, in many species the flowering and fruiting dates may vary somewhat (Greaves 1978) and the level of fruiting may vary tremendously from year to year, depending on seasonal rainfall amounts and patterns, and other factors such as wind or insect damage. Seed years are theoretically predictable from climatic conditions and can be successfully predicted from flowering and fruit set for a few species, such as *Pinus caribaea* sensu Small, non Morelet, which flowers one year and bears seeds the next.

In those portions of the Tropics with a relatively even distribution of rainfall, many species, such as *Roystonea* spp., *Ficus citrifolia* P. Miller, and *Hibiscus elatus* Sw., flower and fruit irregularly throughout the year. Some species, such as *Leucaena leucocephala* (Lam.) de Wit, bear seed more or less continuously in moist habitats, but seasonally in habitats with a strong wet-dry cycle. *Vochysia hondurensis* Sprague in Costa Rica bears fruit twice per year (Nichols and González 1992a, 1992b). Fruiting in some species is thoroughly unpredictable; individual trees fruit irregularly from year to year and by seasons and are not synchronized with others of their species. However, this can be an advantage. If seeds are unavailable on one tree, they may be present on the next tree; or if seeds are unavailable in one locality, they may be available a few kilometers away. *Byrsonima spicata* (Cav.) Kunth, *Cordia sulcata* DC., and *Buchenavia tetraphylla* (Aubl.) Howard illustrate this behavior. Although *Swietenia macrophylla* G. King is usually seasonally synchronized even outside its native range, a few unsynchronized individuals produce some seeds during most of the year. Continuous flowering and fruiting and discontinuous/irregular year-round fruiting is a natural strategy to avoid overloading the demand for pollinators and seed dispersers. Moreover, having a small percentage of the population out of synchrony helps avoid loss of regeneration to irregularities in normal rainfall patterns. To solve the problem of collecting from species with this diverse behavior, phenology should be recorded and collection activities should be planned by species. Collectors should not become discouraged by a few failures.

Delayed and Rare Fruiting

Many species, such as *Bertholletia excelsa* Humb. & Bonpl., do not bear fruit until they become large canopy dominants, a process that may take 50 years or more. In plantations, the process can be shortened to 15 to 25 years and grafted stock will bear fruits in as little as 6 years (Ferraz 1991). Seed orchards exploit the tendency for open-grown trees to bear fruit more quickly and prolifically than forest trees. The abundance and ease of collection from open-grown trees has often led to excessive collection from phenotypically unproven trees in pastures and along streets. *Lagerstroemia speciosa* (L.) Pres. begin fruiting in as little as 3 years, but do not bear viable seeds until about 15 years (Food and Agriculture Organization 1957). Most species of *Bambusa* flower and fruit in regional synchrony only once every few decades, and *Corypha umbraculifera* L., a palm, flowers once at the end of its long life and then dies.

The advantages to collecting seeds of species that can be stored during bumper crop years are numerous. The cost per unit of seed is lower; fewer seeds are damaged by insects; and the seed usually germinate at higher rates (Lamb 1993). A number of healthy exotic trees, such as *Araucaria heterophylla* (Salisb.) Franco in Puerto Rico, do not produce seeds in their new habitats (Francis 1987), and seeds must be imported each season. Ringing, shallow girdling, stem strangulation, stem bending, root pruning, and water supply restriction has shown some promise in promoting seed production, although these methods ultimately injure the trees (Rudolf and others 1974).

Animal Predation

Rodents, monkeys, birds, bats, and grazing animals can quickly eliminate a seed crop in a limited area. Parrots in Central America can consume an entire seed crop of *Acacia aneura* F. Muell. before it ripens (Willan 1995). Although fences, screens, scarecrows, reflectors, and noise makers can successfully reduce or eliminate seed predation, they are usually practical only for seed orchards or concentrations of seed trees. Sometimes seeds can be harvested after they have become viable but before they or the fruits become attractive or accessible to animals. When forest species are scattered, collecting more widely and intensively appears to be the only way to obtain the needed seed stocks. In temperate areas, squirrel caches can be robbed; and in the Tropics, seeds are separated from the manure of predators that have been feeding on the fruit of the desired species.

Insect Infestation

Most species are attacked to some degree by seed insects. Occasionally, species such as *Prosopis juliflora* (Sw.) DC. and *Triplochiton scleroxylon* K. Schum. are so seriously attacked by insects that propagation is limited (Brookman-Amissah 1973, Marrero 1949). In some cases, insecticides can be used to prevent attack and assure good seed crops. *Zanthoxylum flavum* Vahl seeds in Puerto Rico are reduced to $\leq$5 percent viability by a seed weevil (Francis, personal communication 1994; Marrero 1949). A conservation organization was able to produce seeds free of insects and with good germination by spraying with insecticide (Rivera, personal communication). Many types of seeds should also be treated by fumigation, cold treatment, or insecticide application to eliminate insect damage during drying and storage.

Short Period of Availability

For various reasons, fruits or seeds of many species are ripe and available on trees for a very short time, often just a few days. The fruits of *Hyeronima oblonga* Muell. Arg. and *H. alchornioides* Allem. Diss. fall 3 to 4 days after maturity (Nichols and González 1992a, 1992b). In the final stage of ripening, *Pinus caribaea* sensu Small, non Morelet cones change color from green to brown, the cones open, and the seeds are dispersed quickly (Greaves 1978). Frequent field checks are essential to best time seed collection. Because individual trees of a species are often not closely synchronized, collecting from tree to tree can extend the collection season. Often, the collector can lengthen the period of seed collection by moving up an elevational gradient or across a moisture gradient. Some species, such as *Maesopsis eminii* Engl. and *Pouteria* spp., picked up just before ripening, ripen in storage; thus the picking season is lengthened by a few days. The collector must know the species' traits, because some species, such as

Cordia alliodora (Ruiz & Pavon) Oken, stop ripening as soon as they are detached from the tree (Greaves and McCarter 1990). The collector should also study how long seeds of critical species will remain viable on the ground after fruitfall. Collecting diptocarp seeds from the ground, for example, must be carefully timed because a delay of a few days can result in loss of viability (Domingo 1973).

SEED PROCESSING

The basic method of removing seeds from fruit structures by hand is useful for research quantities of seed, and even highly productive for a few species such as *Swietenia* spp., but is too slow for most applications. Traditional methods such as flailing, trampling, grinding with a mortar and pestle, winnowing, floating, or screening are used to clean seeds of some species such as *Albizia procera* (Roxb.) Benth, *Casuarina* spp., *Eucalyptus* spp., *Leucaena leucocephala* (Lam.) deWit, and *Melaleuca* spp. Seeds in clusters and in brittle pods or capsules, such as those of *Acacia farnesiana* (L.) Willd., *Cassia javonica* L., *Parkinsonia aculeata* L., and *Zanthoxylum martinicense* (Lam.) DC., can often be cleaned by using standard research thrashing machines or by breaking them up by gentle hammermilling followed by screening and blowing. Usually, each stage of the operation is adjusted to accommodate the many seed sizes, shapes, and densities.

CHALLENGES TO PROCESSING

Seed Cleaning Difficulties

The seeds of *Ochroma pyramidale* Cav. are covered with a silky wing ("silk") that is time consuming to remove by hand. In an innovative solution, the seeds were thinly spread over a large mesh screen and set on fire. As the silk burned, the seeds fell through and were scarified in the process (Holdridge 1940b). It is often adventitious to de-wing or eliminate other dry parts from seeds or fruits to reduce the bulk for storage or shipping. De-winging machines designed for *Pinus* spp. have also been used to de-wing other species and to remove some unwanted tissue, such as scale tissue and bract points in *Araucaria cunninghamii* Aiton ex D. Don (Haines and Nickles 1987). Because the seeds of *Swietenia* spp. are large and fragile, they are de-winged by hand, but other more resistant seeds, such as *Tectona grandis* L.f., may be cleaned by working sacks of seed against the ground with a foot, then removing debris by blowing.

Many species, such as *Dalbergia sissoo* Roxb., *Guazuma ulmifolia* Lam., *Prosopis juliflora* (Sw.) DC., Lam., and *Tectona grandis* L.f., have very tough pods or capsules. Some, such as *Pterocarpus macrocarpus* Kurz., have fragile seeds within. Others have fruit structures that tightly adhere to the seeds, as in some *Araucaria*s. These seeds can sometimes be separated by hand using knives or clippers but not by any machines currently available. Usually, the pods or capsules are broken into small units and planted as seeds (FAO 1955). When seeds cannot be separated from fruits or debris, they can be planted within their fruits or mixed with debris. This method frequently requires thinning any resulting seedlings that appear in clusters (Francis 1989c). Sometimes, increased germination will justify hand cleaning small lots of seed (Dabral 1976), especially if the seeds are scarce or expensive or if labor is abundant. One ingenious method of cleaning the seeds of sweet podded legumes, such as *Acacia* spp., *Enterolobium cyclocarpum* (Jacq.) Griseb., and *Samanea saman* (Jacq.) Merril, involves feeding the pods to cattle or goats and extracting the cleaned (and scarified) seeds from the manure (National Academy of Sciences 1980).

Another class of cleaning problems occurs when the seeds are encased in fleshy fruits. When the fruit is thin, seeds may sometimes be dried within the fruit and planted with the adhering fruit residues without affecting germination (Food and Agriculture Organization 1955, Stein and others 1974). In some species, adhering fruit can be removed or loosened by promoting rotting or allowing consumption by insects. If the fruits of *Acrocomia media* O.F. Cook are incubated under mulch for several months, the fleshy fruit is reduced to a husk and the seeds are not damaged. This method also afterripens the seeds (Francis 1993a). The same process, with a shorter duration, may be used with *Juglans jamaicensis* C. DC. (Francis and Alemañy 1994).

However, fruit must usually be removed soon after collection to facilitate storage and planting and to prevent damage to the seeds during putrification of the fruit (Pleva 1973). Numerous methods and machines for cleaning fleshy fruits are used. In many nurseries, most fleshy fruits are separated by hand, washed over screens, and dried. This method is the most rapid way to clean many large-seeded species such as *Mammea americana* L. and *Persea americana* Miller. Sometimes soaking the fruits in water for a period of time facilitates separating the seeds (FAO 1955). In wet sieving, the fruits are hand macerated against a screen just small enough to retain the seeds. The fruit pulp is continuously washed away by running water or by swirling the screen in standing water. The cleaned seed is then dried before storage. In a variation of this method, the fruits are pulped with a hand tool or machine before wet sieving. Flotation is also frequently used to separate fruit pulp, debris, and hollow seeds from filled seeds that sink (Stein and others 1974).

Inconvenient Seed Sizes

The most familiar example of giant seed size is *Cocos nucifera* L. These giant seeds must remain in the husk, which limits human carrying to about 10 seeds and requires a great deal of storage and nursery space. Other species, such as *Caryocar villosum* (Aubl.) Pers. and *Mammea americana* L., have large seeds that also may be inconvenient to transport and store in large quantities. Despite these problems, the abundant stored reserves of large seeds often compensate for the inconveniences of size with their excellent germination and impressive early growth.

Very small seeds can also present problems. Because the seeds of *Eucalyptus* ssp. and *Melaleuca quinquenervia* (Cav.) Blake are so small, the fruits must be collected and transported before they open and disperse their seeds. Cleaning dry, small seeds is easy, but cleaning very fine seeds embedded in fleshy fruits, such as *Ficus* spp. and *Muntingia calabura* L, can be difficult. These seeds are usually cleaned by wet sieving and drying, sometimes followed by dry sieving or blowing.

Perishable Seeds

Although usually thought of as a storage and seed handling problem, the short viability (as little as a few days) of some species (Food and Agriculture Organization 1955, National Academy of Sciences 1980) must be considered during collection to facilitate rapid processing and planting or dispatch of seed to the intended user. Another class of seeds, known as recalcitrants, lose their ability to germinate upon drying. They are especially prevalent in humid forests and are more commonly associated with fleshy fruits. The process of germination often begins as soon as the fruit matures. Whenever possible, seed operations with recalcitrant species, such as *Andira inermis* (W. Wright) Kunth ex DC., *Inga vera* Willd., *Persea americana* Miller, and *Thespesia grandiflora* DC., should harvest, clean, and plant the seeds on the same day or within a very short time. If these seeds are to be stored a short time at room temperature, they should be placed in a plastic bag or under wet sacks. Most of the species will withstand refrigeration and can be stored for one to several weeks. An alternative to seed storage is to germinate the seeds and maintain the seedlings in the nursery until needed. Although this is impractical with fast-growing species, slow-growing species such as *Guaiacum officinale* L. can be maintained an extra year in the nursery without difficulty.

Physical and Chemical Defenses

The fruits and seeds of a few species, such as *Pterocarpus angolensis* DC., are armed with spines or bristly hairs that make picking and extraction difficult. Using gloves and other protective clothing and possibly singeing (Kimariyo 1973) or milling the fruits or seeds can facilitate seed handling. In some species, such as *Comocladia* ssp., *Hippomane mancinella* L., and *Sapium laurocerasus* Desf., all parts are toxic, at least when green and especially to sensitive individuals. Others, such as *Sterculia apetala* (Jacq.) Karst., have irritating or allergenic hairs (Little and Wadsworth 1964). A large number of toxic and irritating species are scattered throughout the Tropics. Complete avoidance of these species by sensitive individuals and the use of disposable gloves, gauze masks, and other protective clothing by those who must work with them is strongly recommended.

CONCLUSIONS

A high degree of diversity is common in the Tropics, especially in the humid lowlands. In single-species operations, such as the extensive plantations of *Pinus* spp., natural diversity is irrelevant. But organizations that service a wide variety of users with diverse needs, and ecosystem restoration projects where nature dictates the species to plant, cannot ignore diversity. Poorly known species and species with difficult reproductive characteristics must be accommodated. With a good understanding of biology and ecology, innovative thinking, and a little luck, most of these new species can be collected and grown. In some cases research can provide answers, but for a few species, and for a variety of reasons, consistent collection and processing of viable seeds may be impossible. In a 14-year study of species suitable for revegetation of bauxite mine lands in Trombetas, Brazil, 600 species were evaluated and 160 were grown and outplanted; only 89 taxa demonstrated acceptable survival and growth during the first two years (Knowles and Parrotta 1995).

If diversity is a distinguishing feature of tropical forests, diversity also characterizes seed collection methods in the Tropics. Because the number of species collected is large and the objectives and budgets of seed collecting organizations are varied, a wide array of collection methods must be used. Redundancy is an important feature of high biodiversity; often several alternative species are available to fill any particular need. Seed collectors may not always be successful in harvesting seeds of all the species desired, but by using all the tools available, by taking advantage of seed opportunities as they arise, and by substituting species with similar properties, they can consistently offer an adequate range of seeds and seedlings to users.