Collecting, Processing, and Storing Seeds

8

Tara Luna and Kim M. Wilkinson

Nurseries that work to strengthen and expand the presence of tropical native species are concerned about fostering diverse, strong, and well-adapted populations. For many tropical plants, however, the natural diversity of wild populations has been depleted. Habitat loss has reduced the range and sheer numbers of plants. For plants with commercial value, unsustainable harvesting practices may have reduced the numbers of plants with desirable characteristics while leaving behind inferior plants. The process of depleting a population of the best genetic properties so that future populations are weaker than the original populations is called genetic degradation. Seed collection for plant propagation is an opportunity to reverse trends of genetic degradation and species loss. Nurseries have a key role in conserving the gene pool of native plants. This chapter covers some important principles for genetic diversity and seed source selection; it also includes practical procedures for collecting, processing, and storing seeds.

Facing Page: *Seeds are removed from fruit and cleaned on screens in a shaded outdoor location at the nursery of Reserva Natural, Cañón de San Cristóbal, Barranquitas, Puerto Rico. Photo by Brian F. Daley.*

Understanding Genetic Diversity and Seed Collection Ethics

Before creating a strategy for collecting native plant seeds, it is important to understand some key points regarding genetics and collection ethics. Seed collection strategies must protect genetic diversity for the future both at the collection sites and in the places where the offspring will be planted. On the outplanting sites, good seed collection practices ensure that inbreeding will not become a problem (Withrow-Robinson and Johnson 2006) and that plant populations will be genetically viable to survive and adapt to new stresses. For restoration and conservation projects, maintaining genetic diversity is a key part of project objectives and of the target plant requirements (see Chapter 3, Defining the Target Plant).

Collecting Locally Adapted Native Seeds

It is critical to identify suitable seed collection sites. As much as possible, collect seeds from a habitat similar in elevation, aspect, and soils to that of the outplanting site to ensure local genetic adaptation. In some parts of the world, plant geneticists have defined "seed zones" for native species to show practitioners where locally adapted seed sources can be found for different restoration project locations. It is rare to find these recommendations for native tropical species, however, so collectors just have to do their best. Working with locally adapted plant sources is important not only for the survival and health of the plants, but also for the native birds, insects, and animals that depend on the plants (figure 8.1).

In addition, it is important to be sure the population you plan to collect seed from is of wild origin, not planted by people (BLM/SOS 2011). For example, do not collect seeds of native species that were planted as street trees, in landscaping, or as part of a restoration planting after a disturbance, because the genetic diversity and origin is uncertain. (This guideline does not apply to nonnative cultural and traditional species; although diversity is still important, these plants may be selected cultivars.) More details about choosing a seed collection location are addressed later in this chapter.

Use Collection Methods That Ensure Genetic Diversity

Because reproductive strategies vary by species, no standard collecting procedure exists that will ensure genetic integrity for all species. The Seeds of Success seed-collecting program (part of the Native Plant Materials Development Program, led by the U.S. Bureau of Land Management) has developed a useful general protocol, which is used by many Federal agencies and partners for seed bank collections. Key seed collection practices for ensuring genetic diversity are summarized in table 8.1.

Figure 8.1*—To maximize genetic diversity, observe flowering throughout the season so early, middle, and late bloomers are represented. Different flowering and dispersal times may interact with different pollinators. Photo by Brian F. Daley.*

Why Collect Seed From More Than 50 Individual Plants?
(adapted from BLM/SOS 2011)

Research shows that seed collection from more than 50 individuals results in the greatest proportion of alleles (genetic codes specifying certain traits) present in the field population, while still being practical. Some studies show that at least one copy of 95 percent of the alleles occurring in the population at frequencies of greater than 0.05 can be achieved by sampling from—

1. 30 randomly chosen individuals in a fully outbreeding sexual species, or
2. 59 randomly chosen individuals in a self-fertilizing species.

The reproductive biology of many tropical species has not been studied, and to capture rarer alleles would require an increased sample size. Therefore, collectors are advised to sample from a single population with individuals of the target species in excess of 50 individuals, and to look for populations with larger numbers of plants.

Table 8.1—Seed collection techniques to safeguard genetic diversity of native species. Adapted from USDI BLM/SOS (2011).

Seed collection method	Rationale
Assess the target population and confirm that a sufficient number of individual plants (more than 50) have seeds at natural dispersal stage.	Ensure that adequate genetic diversity can be sampled from the population and that the seeds are likely to be at maximum possible viability and longevity.
Monitor seed maturation and assess insect damage and empty seeds throughout the population before making the seed collection. Carefully examine a small, representative sample of seeds using a cut test and for smaller seeds, a hand lens.	Estimate the frequency of empty or damaged seeds and confirm that the majority of seeds are mature and fully formed. (Seed development can vary within and between populations of the same species.)
Collect seed from more than 50 individuals.	Maximize the genetic diversity present within a collection of seeds. To gather the greatest proportion of alleles (genetic codes specifying certain traits) present in the field population as possible.
Collect from distant individuals to reduce the chance of collecting only close relatives. Collect equally and randomly across the population, maintaining a record of the number of individuals sampled.	Capture the widest possible genetic diversity from the plant population and to avoid only a few genotypes being propagated.
For trees, collect seeds or fruits equally from all parts of the crown—top, sides, and bottom. Gather from individual trees at least 150 ft (50 m) distant from each other (Dawson and Were 1997).	Ensure genetic diversity in tree seed, as these parts of the tree may have been pollinated at different times from different pollinators. Distance recommendation is to avoid collecting from closely related individuals (Dawson and Were 1997).
Return to the site to collect seeds from a population throughout its dispersal season. Collections taken from the same population during a single collecting season may be combined into one collection; do not mix collections between locations or years. Note multiple dates of collections on the seed label.	Maximize genetic diversity in the collection, capturing early, middle, and late bloomers. (These different dispersal times may also interact with different pollinators.)
Collect no more than 20% of the viable seed available at the time of collection.	Ensure that the sampled population is not over collected and is maintainable, so seeds that are needed for natural dispersal or for local fauna will remain available.
Clearly label all bags (inside and out) with the species, date collected, location of collection, and name of collector.	Ensure that each collection is properly identified so seeds can be used appropriately in restoration efforts.

Communicate About Seed Collection

When planning a seed collection strategy, some of these following communications will need to take place:

- In all cases, be sure to obtain landowner permission to collect seeds.
- Before collection, be absolutely certain of the species identification. If in doubt, collect a specimen and get help making a positive identification.
- If any other seed collectors are found using the site, cooperate with them to share the collection work and ensure that the genetic conservation practices described in this chapter are followed.
- Use great care in labeling seed sources and make sure that you, and the people who work with you, do not accidentally mix seeds with those from another plant collection area. Outbreeding depression resulting from the mixing of genotypes can potentially harm the population, resulting in the reduction of fitness and adaptive variation.
- For rare plant propagation, contact the appropriate organization in your area to obtain a collection permit in advance. These programs have jurisdiction over rare species and are responsible for monitoring and protecting the rare plant populations. The guidelines given in this chapter do not apply to threatened and endangered species; check with the appropriate organization to find the correct guidelines for each species in that category.

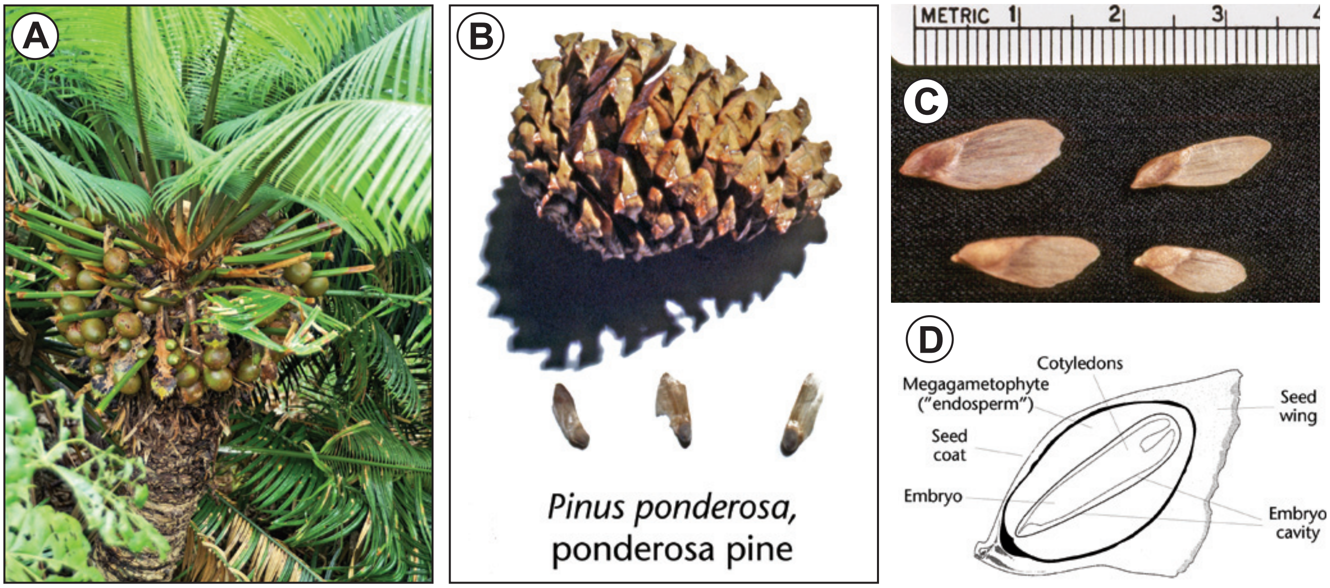


***Figure 8.2**—Cones of gymnosperms can be fleshy or woody at maturity, as seen in* Cycas *(A) and* Pinus *(B) which release winged seeds (B, C). Gymnosperm seeds are composed of the embryo, the nutritive tissue, and the seed coat (D). Photos A, B, and C by Thomas D. Landis, and illustration D from Dumroese and others (1998).*

Protecting the Seed Collection Site

Collection strategies need to be planned to minimize negative effects on the site. Collectors should follow the following steps:

- Avoid soil disturbance and plant damage while collecting seeds.
- Be sure not to overharvest seeds, leaving too few behind for natural regeneration and wildlife needs.
- Avoid collecting from weed-infested areas and do not transport weeds into pristine habitats and rare plant localities.
- If possible, allow collection sites to rest for at least two growing seasons between collections. Keep in mind that longer rest periods may be needed for some species and locations.

Understanding Flowers and Seeds

The tropics support the highest degree of species diversity in the world. It has been estimated that more than 50,000 woody tree and shrub species are in this region. This diversity is also expressed in a wide range of flowers and fruits. Seed collectors and growers need to be able to distinguish fruits and seeds of species that they are collecting to ensure collection of the right structure at the right stage of development.

Plants are classified according to whether they produce spores or seeds. Spore-bearing plants such as ferns produce clusters of spores on the undersides of leaves that may or may not be covered with a papery covering. Spores can be collected like seeds just before they disperse, but they require special growing conditions to develop into plants. Seed-bearing plants are classified into two groups based on their flower types: gymnosperms and angiosperms.

Gymnosperms

Gymnosperms do not bear true flowers and are considered more primitive than angiosperms. Instead, gymnosperms bear male and female cones on the same tree. Male cones typically develop on the tips of branches and fall off after pollen is shed. Female cones enlarge and become more visible following pollination and fertilization, and seeds are borne naked on the mature scales. Gymnosperm cones can be dehiscent, indehiscent, or fleshy. Cones that are fleshy (such as *Cycas*) or surrounded by a fleshy aril (such as *Torreya*) resemble berries and are handled and processed in the same way (figure 8.2A). Dehiscent cones have scales that open at maturity to release the seeds (figure 8.2B) whereas indehiscent cones rely on animals to pry them open and disperse the seeds. In both dehiscent and indehiscent cones the seeds are usually winged (figure 8.2C). Fleshy cones resemble berries and their seeds lack wings. Gymnosperm seeds are composed of the embryo, the nutritive tissue, and the seed coat (figure 8.2D).

Angiosperms

Angiosperms bear true flowers, and seeds are enclosed in an ovary that develops and surrounds the seeds after fertilization. Pollen is transferred from anthers (male reproductive structure) to the stigma surmounting the pistil (female reproductive structure). Following pollination and fertilization, the ovary enlarges into a fruit that contains one to many seeds. The fruit protects the seeds, provides them with nutrition during development, and helps with the dispersal of mature seeds. The seed is a ripened ovule consisting of a seed coat, the nutritive tissue (endosperm), and the embryo (figure 8.3). Embryo size varies widely among species.

Most angiosperms have perfect (bisexual) flowers, meaning they contain both the male and female reproductive structures in the same flower (figure 8.4A). Perfect flowers can be showy or very small and inconspicuous. Some species such as *Swietenia* and *Ricinus* have imperfect flowers, meaning that separate male and female flowers are borne in single sex flower clusters on the same plant (figures 8.4B, 8.4C). Some species are dioecious, such as *Dondonea*, which means that individual plants are either male or female (figures 8.4D, 8.4E). Thus, often only the female plants will bear fruits and seeds (figure 8.4F).

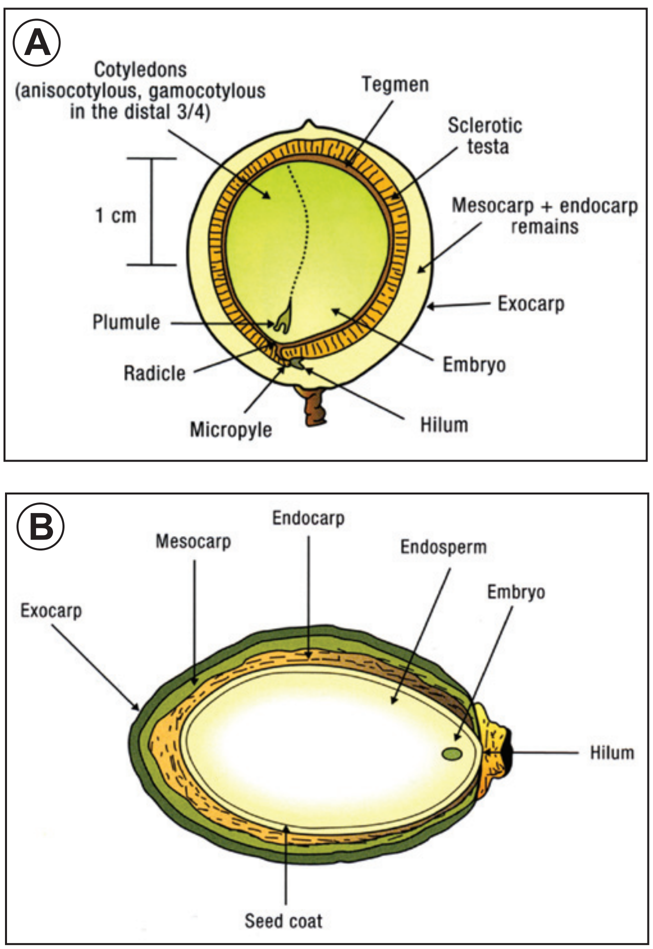


Figure 8.3*—Angiosperm fruits and seeds vary greatly among species;* Calophyllum *(A) and* Minquartia *(B). In some species, the embryo is not visible to the naked eye. Illustrations from Vozzo (2002).*

Because of the wide variety of flower types, resulting fruits also vary tremendously. Dry, dehiscent fruits are those that are woody or papery and split open at maturity. Some examples include capsules (figures 8.5A, 8.5B), some legumes or pods (figure 8.5C), and follicles (figure 8.5D). Dry, indehiscent fruits are those in which both the fruit and seed form an integrated part of the dispersal unit and do not split open at maturity. The thin shells that surround the seeds of these species are fused with the outer layer of the fruit and are dispersed as single units that resemble a seed and often have winged appendages. Examples of dry indehiscent fruits include achenes (figure 8.6A), schizocarps (figure 8.6B), nuts (figure 8.6C), and samaras (figure 8.6D). Some pods and capsules do not open at maturity and are basically handled as indehiscent fruits (figure 8.6E). Fleshy fruits are those where the tissue of the ovary is strongly differentiated. The pericarp is the part of a fruit formed by ripening of the ovary wall. It is organized into three layers: the skin (exocarp), the typically fleshy middle (mesocarp), and the membranous or stony inner layer (endocarp). These layers may become skin-like and leathery, fleshy, or stringy during development. Fleshy fruits such as berries, drupes, and pomes are indehiscent. Berries contain a fleshy pericarp with many seeds (figure 8.7A) while drupes have a tough stony endocarp (known as the stone or pit) that encloses only one seed (figure 8.7B). Furthermore, some fruits are known as aggregate fruits, as seen in *Ficus*, *Annona*, and *Morinda*, which grow in a cluster of multiple fruits developed from a single flower and bear one seed each (figure 8.7C).

Seed Longevity

Concerning longevity, seeds can generally be classified into four groups: viviparous, recalcitrant, intermediate, and orthodox. Viviparous seeds are those that germinate before they are dispersed from the plant. The most common examples are some species of mangroves such as *Avicennia* and *Rhizophora* (figure 8.8A) and some tropical legumes (figure 8.8B).

Recalcitrant seeds only retain viability for a few days, weeks, or months. Most tree species from the humid tropics, where rainfall is distributed on a relatively even basis throughout the year, have recalcitrant seeds (Vozzo 2002). In general, large-seeded species that drop moist from perennial plants in moist habitats are most likely recalcitrant (Hong and Ellis 1996) (figure 8.8C). Recalcitrant species are usually sown in the nursery immediately after collection.

Intermediate seeds are those that can withstand some degree of desiccation and storage at low temperatures, but they cannot tolerate freezing. Papaya has been stored suc-

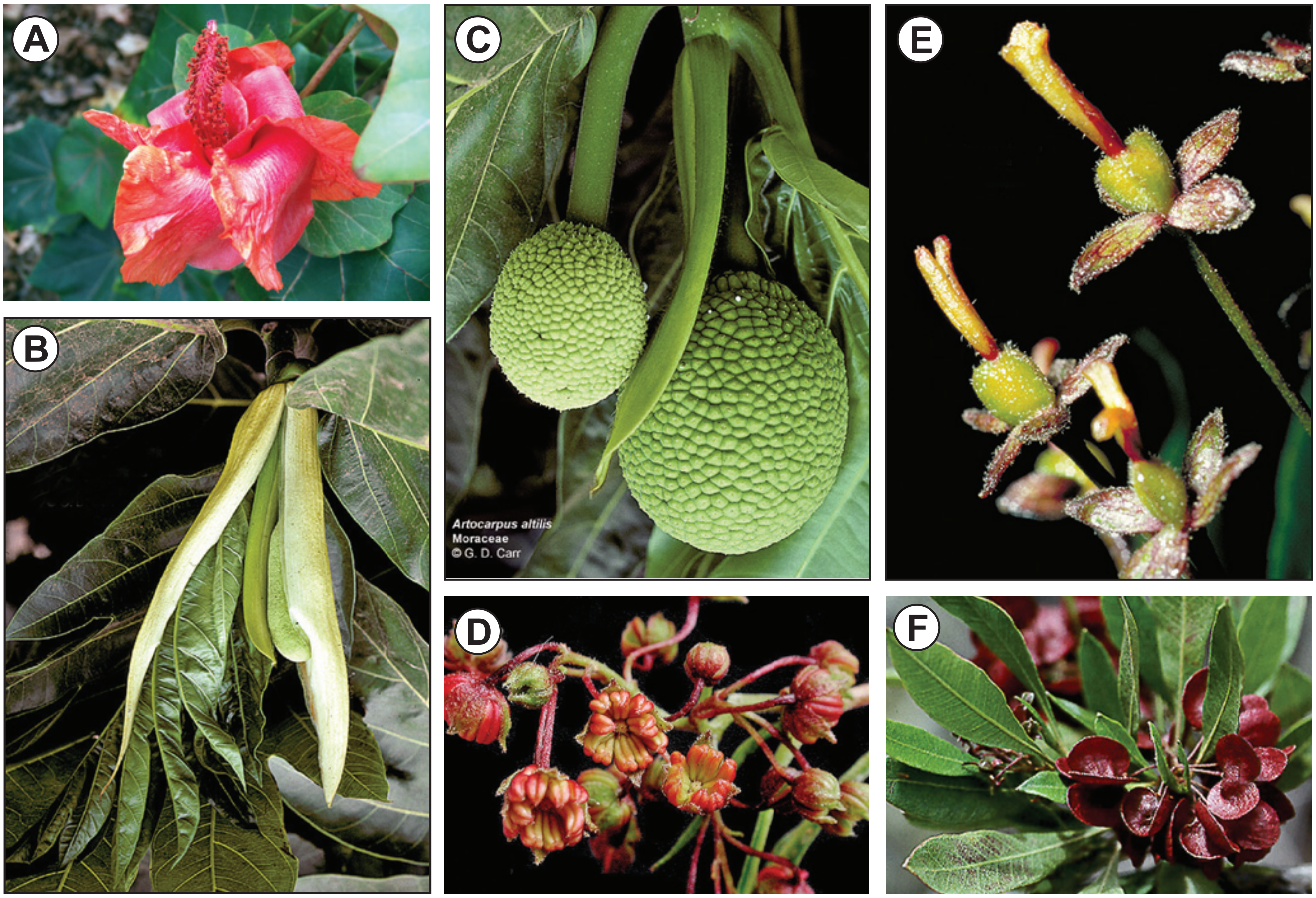
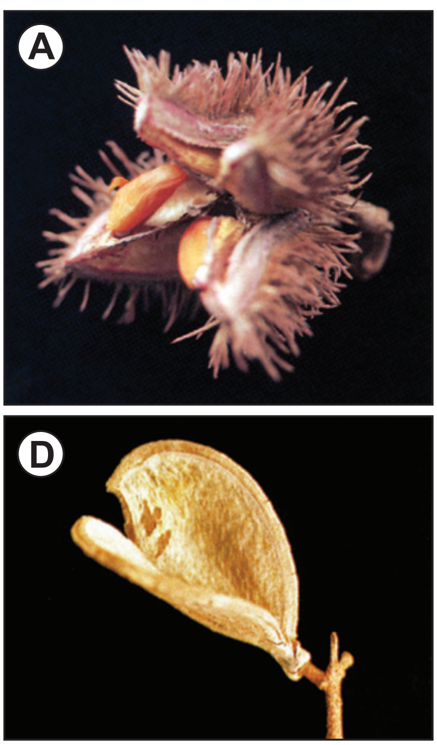


Figure 8.4—*Examples of flowers: Perfect bisexual flower of Hawaiian kokia (*Kokia drynarioides*) (A). Imperfect male (B) and female (C) flowers can occur on the same monoecious plant, as with* Artocarpus *species; imperfect dioecious flowers borne on separate plants of* Dodonaea viscosa*: male flowers (D), female flowers (E), mature seed capsules on a female plant (F). Photo A by Tara Luna, photos B, C, D, and E by Gerald D. Carr, and photo F by C.H. Lamoureux, courtesy of Gerald D. Carr.*



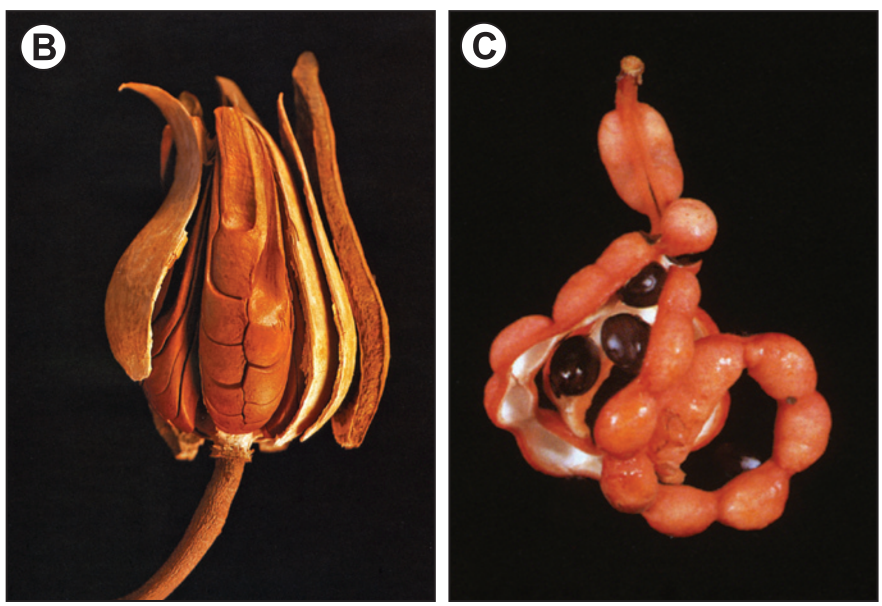


Figure 8.5—*Dry dehiscent fruits such as capsules (*Slonanea *species) (A) and* Swietenia *(B), legumes or pods (*Acacia*) (C), and follicles (*Roupala montana*) (D). Photos from Vozzo (2002).*

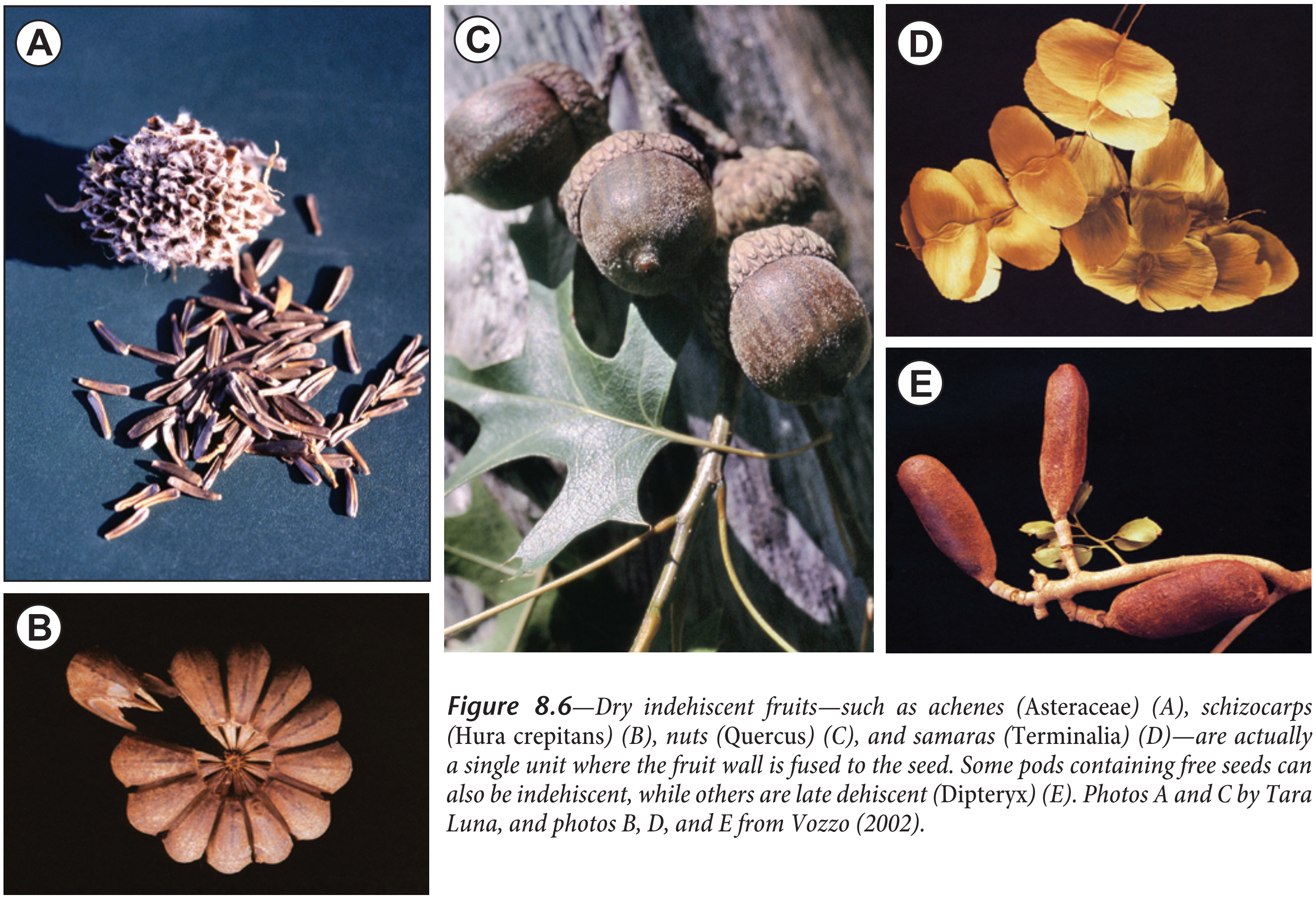


*Figure 8.6—Dry indehiscent fruits—such as achenes (*Asteraceae*) (A), schizocarps (*Hura crepitans*) (B), nuts (*Quercus*) (C), and samaras (*Terminalia*) (D)—are actually a single unit where the fruit wall is fused to the seed. Some pods containing free seeds can also be indehiscent, while others are late dehiscent (*Dipteryx*) (E). Photos A and C by Tara Luna, and photos B, D, and E from Vozzo (2002).*

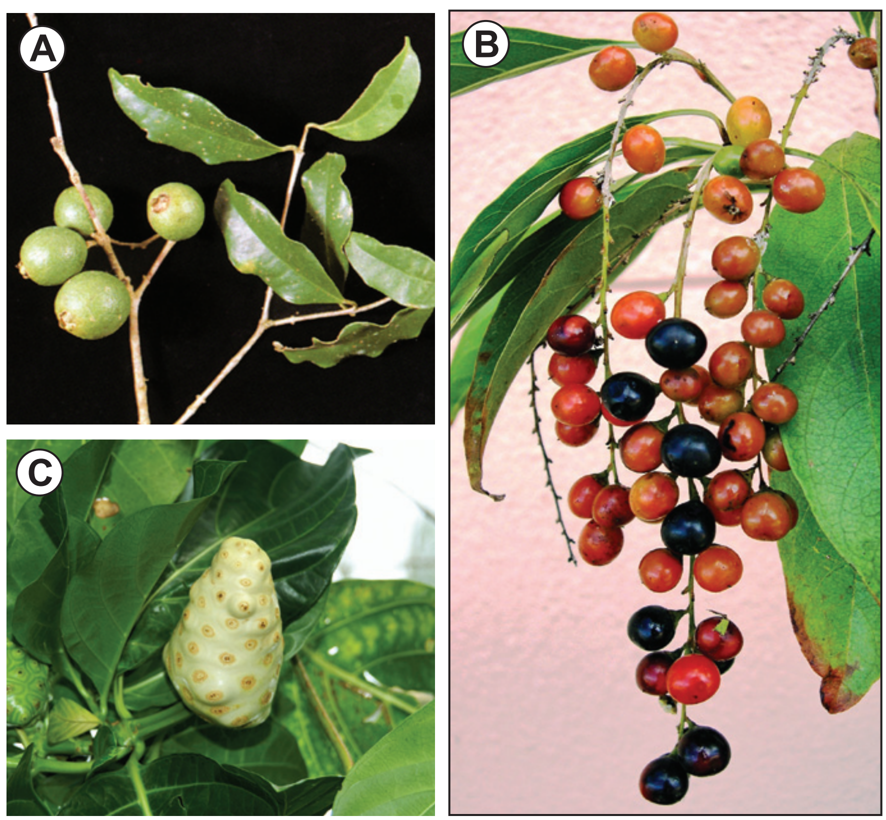


*Figure 8.7—Berries contain numerous seeds per fruit (A) (*Myrica species*), while drupes usually contain one seed surrounded by a stony pit (B) (*Citharexylum spinosum*). Noni (*Morinda citrifolia*) is an example of an aggregate fruit (C). Photo A from Vozzo (2002), photo B by Brian F. Daley, and photo C by Thomas D. Landis.*

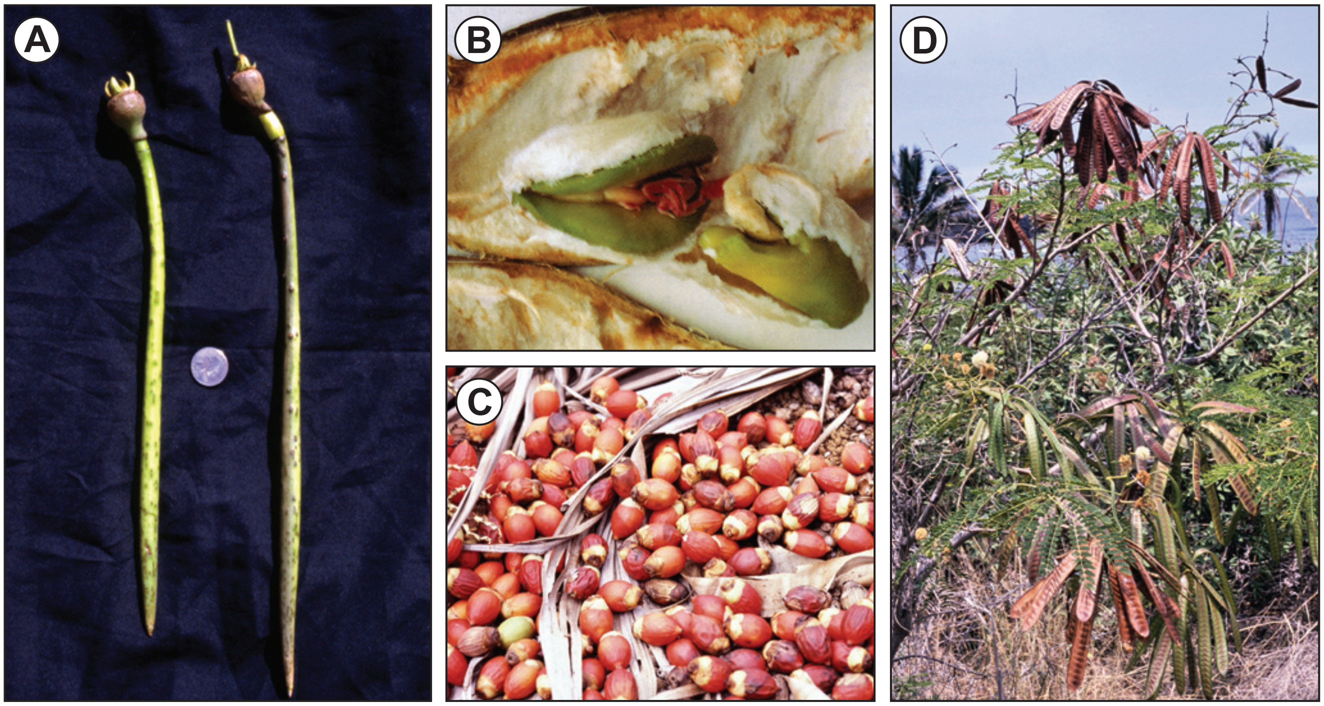


Figure 8.8—Viviparous seeds germinate and develop into a propagule before they disperse as seen in some mangroves (A), or while still enclosed in the fruit in some tropical legumes (B). Recalcitrant seeds, like palms (C), need to be collected before they germinate or lose their viability. Orthodox seeds, such as Leucaena *species (D), typically have hard seed coats. Photo A by Thomas D. Landis, photo B from Vozzo (2002), and photos C and D by Tara Luna.*

cessfully under conditions of 50-percent relative humidity with seeds dried to 10-percent moisture content for 6 years without affecting viability (Vozzo 2002). Other species that have shown intermediate storage behavior include neem, cinnamon, citrus, and coffee.

Orthodox seeds store easily for long periods of time because they tolerate desiccation. Tropical species that occur in areas of strong wet-dry seasonal cycles or semiarid environments along the coast often have orthodox seeds (figure 8.8D). In general, dry, hard seed coats and small seeds from dry, dehiscent fruits are most likely to be orthodox.

Collecting Seeds

Effective native seed collection involves a number of steps to ensure quality seeds are collected at the right stage. Proper seed collection requires the following practices:

- Locate populations of desired species before or during flowering.
- Investigate the viability of seeds after dispersal or maturation on a species-by-species basis.
- Monitor potential sites directly after flowering when fruits are becoming visible.
- Record the dates of flower, fruit, and cone formation. Cones are often a 2-year crop, so you can assess cone crop the year before collection.
- Observe carefully the weather patterns during pollination, fruit formation, and maturation.
- Visit the site frequently to monitor the development and quality of the seed crop.
- Use collection dates from previous years to predict target collection dates and other information.
- Use a cutting test of a few sample seeds to determine maturity before collection.
- Collect seeds during dry weather, if possible.

Selecting Locally Adapted, Genetically Diverse Seed Sources

The genetics discussion at the beginning of this chapter detailed essential elements of seed collection to ensure local adaptedness and genetic diversity. These elements include collecting from a minimum of 50 individuals; collecting from distant individuals to reduce the risk of collecting only close relatives; collecting equally and randomly across the population; and collecting throughout the seed dispersal season (BLM/SOS 2011) (figures 8.9A, 8.9B). Choosing a seed collection site is crucial to ensuring that locally adapted, genetically appropriate materials are planted. Within each species are genetic variations. Local populations of native plants have adapted to local climate, soils, elevation, precipitation, environmental stresses such as wind or drought, and other site conditions. Local native plant materials, collected from the same or similar habitats as the outplanting site, have been shown to perform better than nonlocal sources. Because seed zones have not been defined for most native tropical species, seed collectors must decide on a case-by-case basis what makes sense, considering climate, soil type, elevation, and other site conditions (Withrow-Robinson and Johnson 2006). Collectors should collect seeds from plants with high vigor and health. Collecting seeds from, and propagating, locally adapted plant sources improves not only survival and growth of the plants on the outplanting site, but also is important for the survival of native fauna, from insects to birds, that depend on these plants.

Selecting for Desired Characteristics

Tropical nurseries collect seeds for diverse clients and projects. Nursery-grown plants can be planted for many reasons: traditional uses, ornamental plantings, agroforestry, habitat restoration, silviculture, or a combination of these uses. Plants within a population can vary dramatically in their characteristics, such as the qualities, properties, and productivity of their fruit, wood, or medicinal products. For some projects, seed collectors may want to select for certain desired characteristics. Some of the desired characteristics (especially medicinal properties) may be difficult for seed collectors to discern. If in doubt, collectors can ask for help from end-users and clients to choose parent plants with preferred properties.

Seed selection may be for disease resistance. Depending on the disease vector, some plants showing obvious pest or disease problems may pass on that susceptibility to their offspring. Thriving local plants are excellent candidates as parents.

For plants with food, wood, fiber, or other uses, high productivity in terms of abundant fruit, nuts, foliage, or fast growth rate is often desired. Many native tropical species only produce large seed crops periodically. Heavy seed crops are often followed by light seed crops the following year. The interval between heavy seed bearing years is referred to as

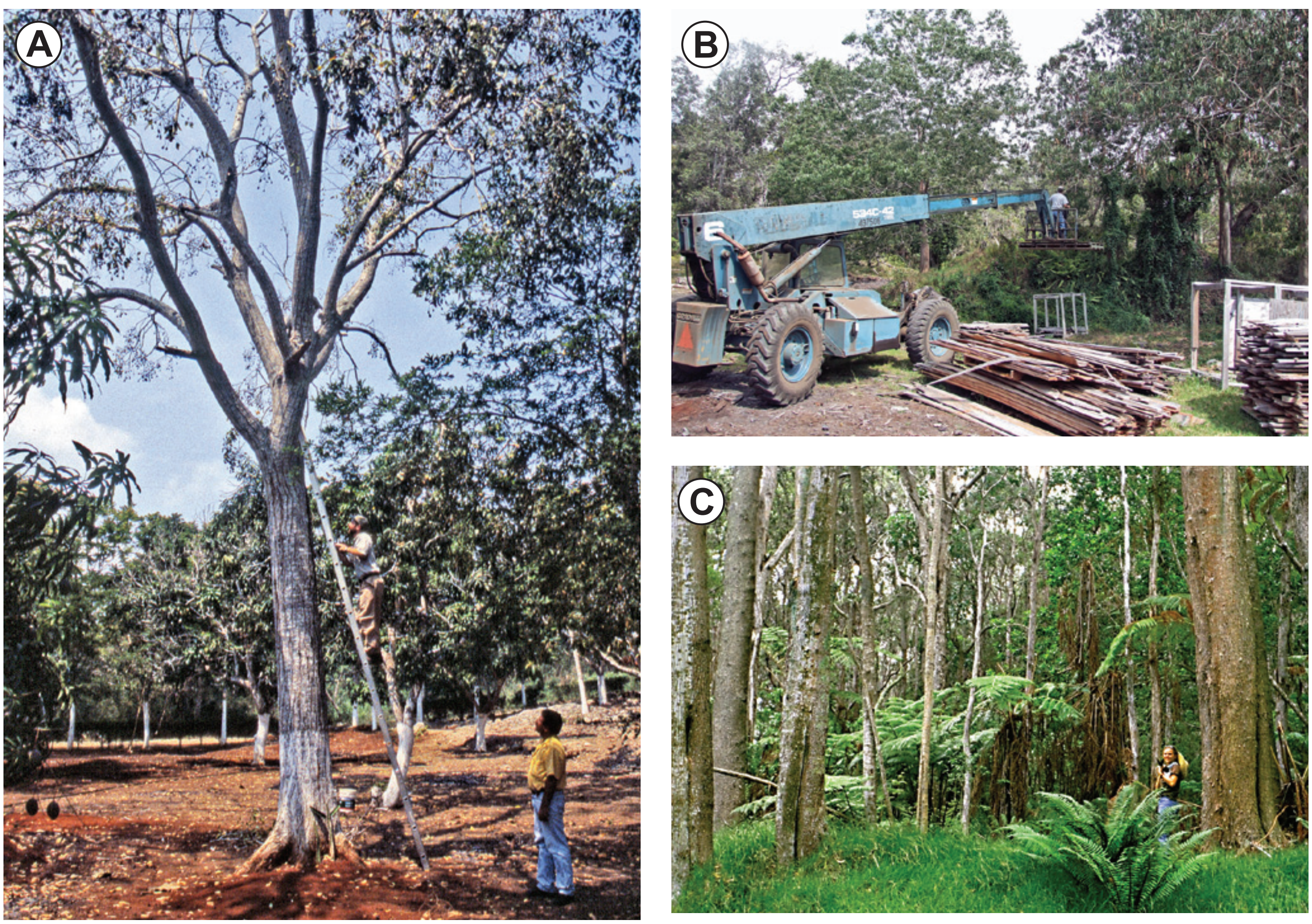


Figure 8.9*—Good tree seed collection practices to maximize genetic diversity include collecting from individuals at least 150 feet (50 m) apart, collecting throughout the seed dispersal season, and collecting from throughout the canopy. Tools including pole pruners, ladders (A) and even equipment such as forklifts (B) are useful to help access the desired diversity. In addition to protecting genetic diversity, seed collection may involve selecting for certain desirable traits, such as the "canoe koa": straight-boled, healthy, large trees (C). Photo A by Thomas D. Landis, photo B by Clark Allred, and photo C by Craig R. Elevitch.*

periodicity. Depending on the goals of the project, collecting seeds across different periods may be advisable. For example, when restoring pollinator habitat or food for birds, continuity of supply even in sparse years is important.

For woody plants, growth form is also a key characteristic. For example, trees may range in form from small, multistemmed, shrubby individuals to large, straight-stemmed individuals. Depending on the preferred characteristics for the project needs, seed collectors can gather seeds from parents with the desired form. For example, in Hawai‘i, the renaissance of traditional Hawaiian canoe culture has regenerated interest in the koa tree, a species that can range from shrubby and branchy to tall and straight in form. "Canoe koa," which are straight-boled, tall trees good for canoe making, are sought for some koa reforestation projects (figure 8.9C).

Choosing Quality Over Quantity When Collecting Seeds

Seed collecting is definitely an area where "quality over quantity" needs to be the standard to avoid perpetuating undesirable characteristics and eroding genetic diversity of the species. For example, sometimes plants produce high volumes of seed when they are stressed, diseased, or injured but those seeds may not be of high quality. Also, for tree seeds, it is much easier to collect from short, seedy, shrubby individuals than from tall, straight trees but collecting only from those easiest to reach results in less genetic diversity. For all plants, it is faster to collect from only a few individuals than to follow the recommendation to take small amounts from 50 or more individuals, but collecting with the goal of gathering the most seeds in the least amount of time is not an effective strategy. If working with contractors or nursery staff to collect seeds, it is recommended to pay collectors by the hour instead of by the pound, so that proper guidelines that ensure seed quality and protect genetic diversity are followed. The long-term ecological viability and future contribution of a planting is at stake.

Species Phenology

Monitoring species phenology (development throughout the season including flowering, fruiting and producing, and dropping leaves) is an important part of seed collection. Any observations may also provide clues on how to germinate the seeds. Good field experience has no substitute.

Be sure to record time and dates of flowering for each species. Flowering is easily observed in species with showy flowers but requires more attention for wind-pollinated species such as *Podocarpus* and *Terminalia*. Over time, recognizing the flowering sequence of the local flora enables staff to simplify the seed collection schedule by keying it to the flowering period of a few index species. Most developing fruits become visible only a few weeks after flowering and pollination. As you become familiar with the phenology of the species and local site conditions, you will be able to develop a seed collection schedule that is specific for your area.

Each species has its own flower and fruit arrangement, pollination strategy, and mode of seed dispersal. Some species will flower and fruit over an extended period of time while others will flower and fruit only once during a growing season. Different types of flower arrangements will have different blooming sequences. In tropical areas with a strong wet-dry seasonal cycle, most species will flower and fruit during defined periods. In tropical areas with an even distribution of rainfall, many species will flower and fruit irregularly throughout the year. These species produce several distinct fruit crops in 1 year within individual plants. For broad genetic representation, you will need to collect fruits from all periods of seed availability.

Fruits of many tropical species are available only for a short time after maturation. Some fleshy fruits can be picked before full maturation and ripened at the nursery without affecting seed viability. Other species will fail to ripen after they are detached from the tree. Collectors will also need to know how long the seeds of a species will remain viable on the ground. Collecting seeds from the ground needs to be timed correctly because a delay can result in loss of seed viability.

Often, a range of fruit maturity stages exists within a single plant. For example, some species have a flower stalk with a prolonged period of flowering and many different stages of fruit development. The seed collector will need to selectively harvest only the fully mature fruits and make repeated visits back to the collection site.

Be aware of the dispersal strategy of the species before attempting to collect seeds. Tropical fruits have developed many highly specialized strategies that aid in seed protection and seed dispersal away from the parent plant. Many species are dispersed by animals, including bats, monkeys, birds, and ants for which the fleshy fruits are food sources. Collectors need to time their collection before the fruit is consumed; in some cases, it may be necessary to bag or cage fruits to obtain seeds. Remember seed collection ethics and be sure to leave enough food for the native animals when collecting seeds.

Wind dispersal is very common for many tropical species. Seeds and fruits can have air-filled cavities, hair-like coverings, and various kinds of wings or parachutes (figure 8.10). Collectors need to time collection before seed dispersal and before windy days.

Some species such as *Cassia* and *Mimosa* disperse by force upon maturation. In these cases, you may need to bag the

***Figure 8.10**—Species that are wind dispersed must be collected as soon as they are mature. Shown:* Heliocarpus appendiculatus. *Photo from of Vozzo (2002).*

developing fruits with cloth to capture the seeds (figure 8.11). Use a fine mesh cloth with a weave that allows light transmission but is small enough to prevent the seeds from falling through the cloth. Tie the bags over developing seed stalks so seeds will be captured when they are dispersed by force.

Factors Affecting Seed Formation and Collection Timing

Environmental conditions can be either beneficial or detrimental to flowering and seed development. For example, drought and high temperatures may promote flowering, but prolonged moisture stress may cause plants to abort developing fruits and seeds or to have poor seed viability. Perform a cutting test on seeds directly before collection, as described in the following section.

Elevation, latitude, and aspect affect seed maturation because it is temperature dependent. Populations found on open, sun-facing slopes (south-facing north of the equator, north-facing south of the equator) will mature sooner than those on protected, shade-facing slopes. Low-elevation populations usually mature first, and seed collectors can follow seed maturity up slope with increasing elevation. Collectors should use favorable microenvironments to their advantage. For example, populations growing in full sunlight tend to produce more seeds than those that are heavily shaded. Plants growing on moist and nutrient rich soils will produce more and healthier seeds. Sites intensely browsed by livestock are poor choices for seed collection because animals often consume the current season's growth, which limits flowering and seed production. Wildlife can quickly eliminate a maturing seed crop, and collectors may need to bag or cage developing fruits. Certain insects and fungi may also consume seeds. Fruits or seeds that have small exit holes, are discolored, or are misshapen must be avoided.

Ensuring That Seeds Are Healthy

The easiest way to ensure that seeds are healthy and ready for harvest is to use a cut test. A cut test allows you to inspect for mature, abnormal, infested, or empty seeds. Several seeds from several individuals within the population need to be examined. The two essential tools are a hand lens and a safety razor, knife, or scalpel for cutting. With care, cut the fruit or seed along its longest axis. Inspect the seeds for their internal coloring, how completely the internal tissue fills the seed coat cavity, and for the presence of an embryo. Depending on species, the embryo may completely fill the cavity or be tiny and embedded in the endosperm. (A microscope may be needed for examining very small-seeded species.) If the seed coat is soft and the contents are watery and soft, the seed is immature. If the seed coat is hard and the contents are firm and light tan to white in color, the seed

***Figure 8.11**—Seeds that disseminate by force with explosive capsules are best collected by tying mesh bags over the developing fruits. Photo by Tara Luna.*

is approaching maturity or is fully mature. Some species can be collected just before maturity if the entire inflorescence is cut and the seeds are allowed to cure properly before cleaning. In general, the optimum time for seed collection is when fruits are splitting open at the top.

Seed Collection Methods

The choice of seed collection method depends on the species to be collected. Some general collection methods include hand picking or hand stripping, collecting by hand from the ground after seeds have fallen, cutting fruit clusters, raking or shaking branches over a canvas tarp, bagging or caging developing fruits or cones, and tying canvas tarps between large woody plants. The following tools and supplies are useful when collecting seeds from natural stands:

- Labels, permanent markers, pencils, and seed collection forms to attach to bags.
- Scissors, pruning shears, and extendible pruning poles, or safety and tree climbing gear for taller trees.
- Hand lens to examine seeds to ensure they are full.
- Safety razor blades or sharp pocketknife for the cutting test of seeds and to examine fruits.
- Large paper bags for dry fruits.
- White plastic bags for fleshy fruits.
- Canvas tarps for collecting fruits from the ground.
- Hand gloves.
- Wooden trays for collecting seeds of low-growing plants.
- A storage box or cooler to keep collections from being overheated during transport.
- Binoculars for spotting fruits in taller trees.
- Fine mesh bags, cages, fine mesh cloth, and rubber bands for species with rapid dispersal.

Purchasing Seeds From a Reputable Source

Collecting yourself or contracting seed collection according to your specifications is the best way to ensure you get locally adapted, genetically diverse sources. Sometimes, however, you may need to buy seeds. If purchasing from a seed supplier without overseeing collection practices, it is best to ask what sources the company has available, rather than asking for a particular source—unscrupulous suppliers may claim to have exactly what you want. If you cannot locate a suitable source of seeds for purchase, it is best to collect your own. If your seed suppliers are willing and able to collect to your specifications, have them follow the guidelines provided in this chapter.

Purchased seeds must be of a high quality and free of weeds. When purchasing seeds, obtain and keep a certificate of the seed analysis for each seedlot. The seed analysis must have the scientific name of the species, cultivated variety (if applicable), origin of the seeds, an estimate of viability, the percentage of pure live seeds (PLS—discussed in the following section under Seed Testing), and the percentage of other crop seeds, weed seeds, and inert material. Purchase only seeds with high PLS values and very low percentages of weed seeds and other inert materials. It is often a good idea to ask about where the seeds were collected and to determine what weeds may be present in the seedlot.

Processing Seeds

The way in which seeds and fruits are handled during collection, temporary storage, postharvest handling, and cleaning can directly affect seed quality, viability, and storage life. Proper processing of fruits and seeds begins the moment the fruit or seed is removed from the parent plant. Proper processing includes short-term handling from the field back to the nursery, temporary storage at the nursery, and prompt and proper seed extraction if necessary. This step is followed by prompt and proper planting in the nursery (recalcitrant and orthodox seeds) or preparation for long-term storage (orthodox seeds).

In general, it is best to transport material from the field to the nursery as quickly as possible, avoiding exposure to direct sun, high temperatures, and physical abuse. Dry fruits, seeds, and cones can be left inside their paper collection bags for short durations. Placing plastic bags filled with fleshy fruits inside coolers will help prevent them from fermenting and being damaged by subsequent high temperatures.

Seed cleaning is necessary before sowing or long-term storage. In some cases, seeds will germinate slowly, or not at all, if they are not removed from the fruits.

Most tropical nurseries deal with small seedlots. Seed cleaning and processing can be laborious and time consuming, and specialized cleaning equipment can be expensive. A variety of inexpensive, low-tech methods and devices are easy to use, readily available, and work very well with a variety of fruit types. Some are described in the following sections. Whichever method of cleaning you choose, the seed cleaning area of the nursery needs to be well ventilated. Some fruits can cause allergic reactions, and fine dust can irritate skin, eyes, and lungs. It is important to wear gloves and dust masks during cleaning and to wash your hands afterward.

Recalcitrant Seeds

Recalcitrant seeds cannot withstand drying below a critical moisture level, so they are usually sown immediately after processing. During temporary storage before sowing, seeds must be kept fully hydrated by keeping them in trays under moist burlap or in plastic bags filled with moistened sand or peat moss in a shaded area with relatively cool temperatures. Relative humidity needs to be maintained at 80 to 90 percent.

Many species with recalcitrant seeds can be collected quite cleanly and are sown immediately without further cleaning. Others need additional cleaning that is typically accomplished by flotation in water. Immediately after collection, seeds are placed in a bucket of water. In general, the viable seeds sink whereas the nonviable seeds, trash, and debris float. As a side benefit, the soaking helps keep the seeds hydrated until they are sown. If seeds or fruits are collected from very dry ground, viable seeds may also temporarily float—a longer soak duration, perhaps even overnight, may be necessary to allow enough time for good seeds and fruits to hydrate and sink. Do a cut test to fine-tune this procedure.

Dry Fruits and Cones With Intermediate or Orthodox Seeds

After they arrive at the nursery, small quantities of dry fruits and cones can be dried in paper bags or envelopes as long as the contents are loose. Large quantities must be dried immediately by spreading the material evenly on a tarp or drying rack. A drying rack consisting of a simple wooden frame with multiple screens can be constructed at low cost and will make efficient use of space in a seed-drying room or greenhouse (figure 8.12). Drying racks can be made with mesh screens having fine holes that allow air movement but prevent seed loss. Different mesh screens will be necessary for different seed sizes. The materials will need to be turned several times per day to prevent it from becoming too hot, drying unevenly, or becoming moldy. Dry, dehiscent fruits, should also be covered with a fine mesh cloth as well to prevent the loss of seeds after fruits open. Good air movement, low relative humidity, and temperatures between 65 to 80 °F (18 to 27 °C) promote even drying and eliminate moisture buildup that can cause mold and damaging temperature. A ventilated greenhouse or storage shed works well for this purpose. Temperature control is very important; use a shade cloth to keep temperatures from rising too high. Avoid rewetting dry fruits after collection. Also, make sure to exclude animals from your seed-drying area.

Separating seeds from dry, dehiscent fruits is usually easy because the fruits split open at maturity. Shaking the fruit inside paper bags so that the seeds fall out will readily separate small lots of seeds and the woody capsules can then be removed from the bag. Modified kitchen blenders with rubber-coated blades are very useful for cleaning small lots of dry fruits (Thomas 2003). The ideal amount of dry fruit material to place in a blender varies with its size, but one-fourth to one-third of storage capacity of the blender works well (Scianna 2004).

Screening is the easiest way to separate extracted seeds from debris such as dry leaves, wings, and small pieces of dried fruits. Screens can be constructed of hardware cloth and wooden frames. Commercial screens are also available in a range of sizes (figure 8.13A). At least two screen sizes

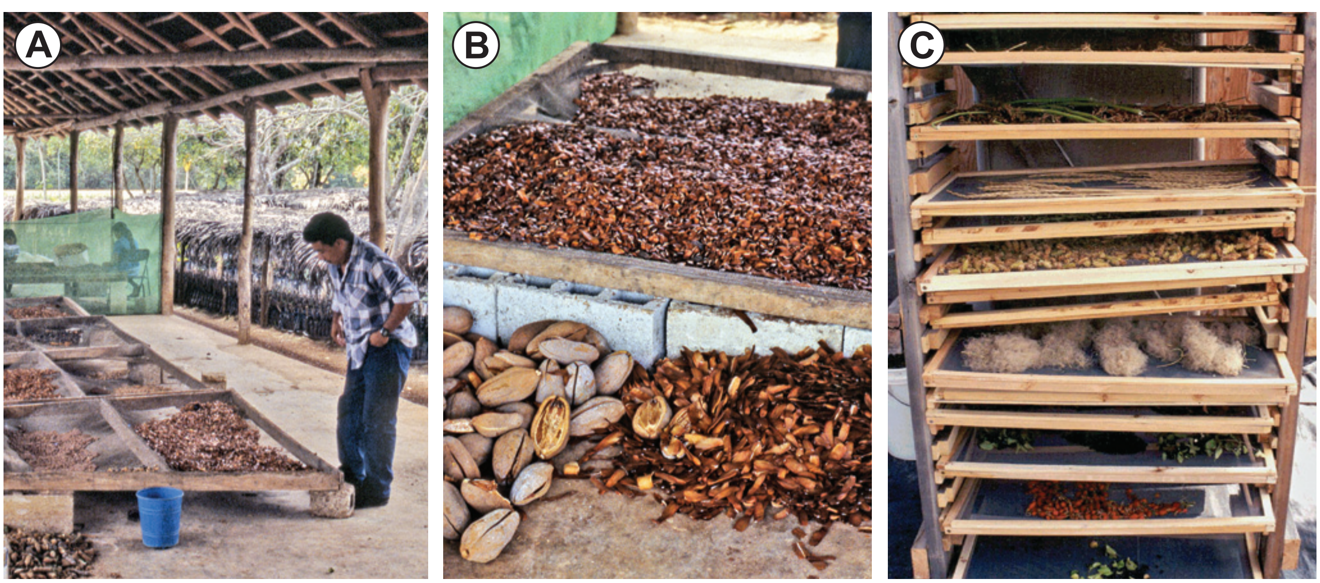


Figure 8.12—Orthodox seeds require protection from wind during drying (A) and good ventilation to prevent mold development during post harvest handling and drying (B and C). Photos by Thomas D. Landis.

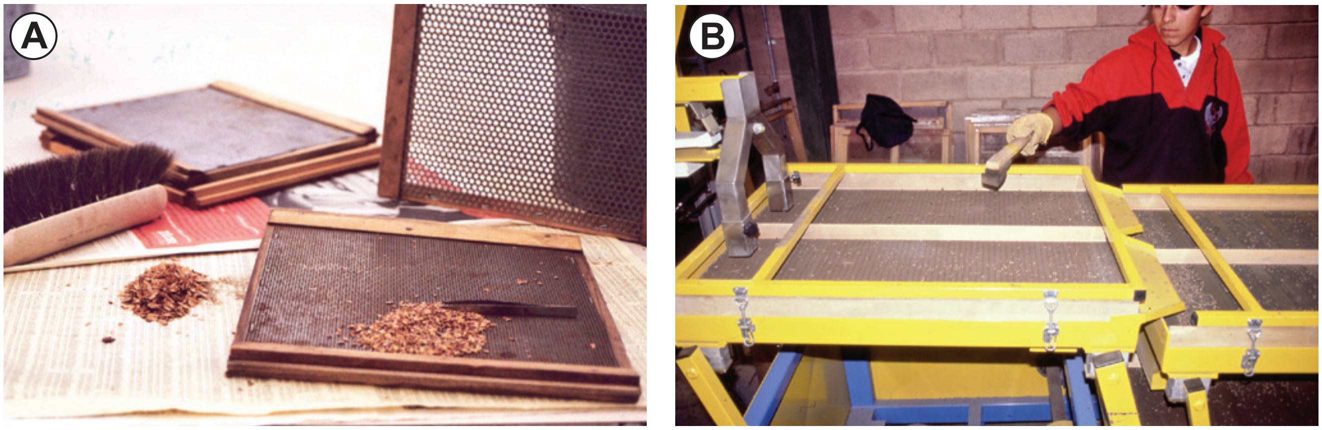


***Figure 8.13**—Screens are used to separate large debris and fine chaff from the seeds and are available commercially in a wide range of screen holes sizes to compliment any species (A). Seeds of many species are very small and require fine screens or sieves for cleaning (B). Photo A by Tara Luna, and photo B by Thomas D. Landis.*

are needed. The top screen has openings large enough to allow the fruits and seeds to pass through, and the bottom screen has smaller openings that allow fine chaff, but not the seeds, to pass through. By placing the collected material on the top screen and shaking, most of the debris can be removed. When separating other small-seeded plants, such as sedges, rushes, and other tropical herbaceous species, you will need screens with very fine mesh or kitchen sieves to properly separate seeds from other debris (figure 8.13B).

If you are cleaning large, tough, leathery pods, you may need pliers, hammers, vices, or screwdrivers. Seeds that are contained in tough woody capsules can be extracted by heating the capsules in ovens or exposing them to fire in a portable barbecue grill. The heat treatment causes the pods to become brittle, which aids in the extraction of the seeds using hand tools. When using fire or heat and hand tools, be certain to not damage the seeds. By simply immersing them in water to separate fine chaff and other impurities, species with hard seed coats can be cleaned.

Conifer cones, after the scales open, can be placed in sack and shaken by hand or tumbled in a wire cage to dislodge seeds from the cone scales. Serotinous cones, such as those found on some tropical pines, require exposure to heat before the scales open. Cones need to be exposed to 170° F (77° C) temperatures by placing the cones in ovens for a period of a few minutes to a few hours or by dipping them in hot water for a few minutes. If an oven is used, cones will need to be checked frequently during drying and removed when most have opened enough to allow the extraction of seeds. If the cones are dipped in hot water, the combination of heat and drying after the soak needs to be sufficient to open them. Most tropical conifer seeds are dewinged before sowing, which can be done by filling a burlap or cloth sack one-fourth full, tying or folding it shut, and gently kneading the seeds by squeezing and rubbing from outside the sack for a few minutes to detach the wings (figure 8.14). Repeat the screening process again with a mesh size that retains seeds but allows the smallest debris to pass through (Dumroese and others 1998). This method can be used on other winged tropical seeds as long as it does not damage the seeds. In cases where damage is a possibility, seeds are not dewinged and are planted as an intact unit.

The final step is fanning or winnowing, which separates detached wings, hollow seeds, and seed-sized impurities from good seeds (figure 8.15). When seeds are poured slowly in front of a small electric fan, they separate according to weight

***Figure 8.14**—Conifer seeds are dewinged before sowing by gently kneading them in a cloth or burlap sack. Photo by Thomas D. Landis.*

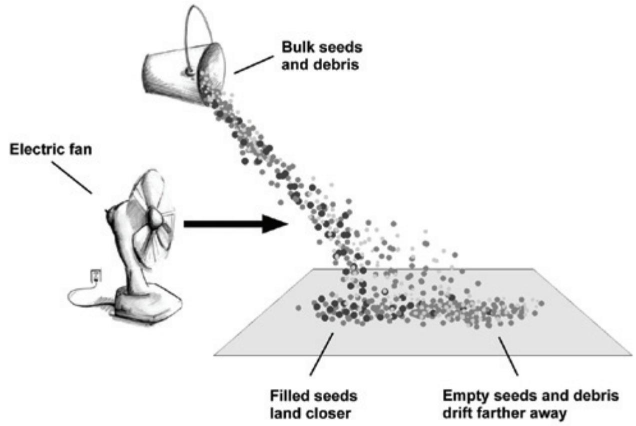


Figure 8.15—*Use a small fan to winnow empty seeds and wings from filled seeds. The heavier filled seeds will land closer to the fan while lighter, empty seeds will land farther away. Illustration from Dumroese and others (1998).*

from the base of the fan. Most heavy, sound seeds will come to rest near the base of the fan while hollow seeds, wings, and lighter impurities will tend to blow farther away. Moving from the fan outward, periodically collect a small sample of seeds and cut them in half to check for soundness, determining where the hollow seeds are and discarding them. All species will probably require several successive separations to obtain a desired degree of seed purity. A good target for most species is 90 percent or more sound seeds (Dumroese and others 1998).

Fleshy Fruits and Cones

Fleshy fruits and cones are very susceptible to fermentation, mummification, excessive heating, or microbial infestation, all of which can damage seeds. On the other hand, it is important not to let the fruits dry out because it can make cleaning them much more difficult. The best procedure is to temporarily store fleshy fruits in white plastic bags in a cool place or refrigerator until the seeds can be processed.

Seeds in fleshy fruits need to be processed shortly after collection. The first step in cleaning is to soak fleshy fruits in water to soften the pulp. The soak may need to last a few hours to a few days, depending on the species, and the water needs to be changed every few hours. After the pulp is soft, flesh can be removed by hand squeezing or mashing using a wooden block, rolling pin, or other device. The flesh can also be removed by wet screening, which involves hand-rubbing the fruits against screens using a steady stream of water to eliminate the pulp (figure 8.16). This method is used for most large fleshy tropical fruits. Another useful tool that can be used for small lots of fleshy fruits is the common kitchen blender or food processor with modified blades. Modified kitchen blenders can be used for small lots of fleshy and dry fruits after the impeller blades are coated with rubberized plastic coating (the material used to coat hand-tool handles) to prevent damage to the seeds (figure 8.17) (Thomas 2003). Run them for about 1 minute to produce a puree of fruit and seeds. The puree should be placed in a bucket and water added slowly and continually resulting in most of the debris floating off and leaving clean seeds at the bottom of the bucket (Truscott 2004). Small, hobby-size rock tumblers (figure 8.18) are also useful for cleaning small fleshy fruits or removing barbs or other appendages from seeds and fruits. Wet tumbling uses pea gravel or crushed stones and water in a

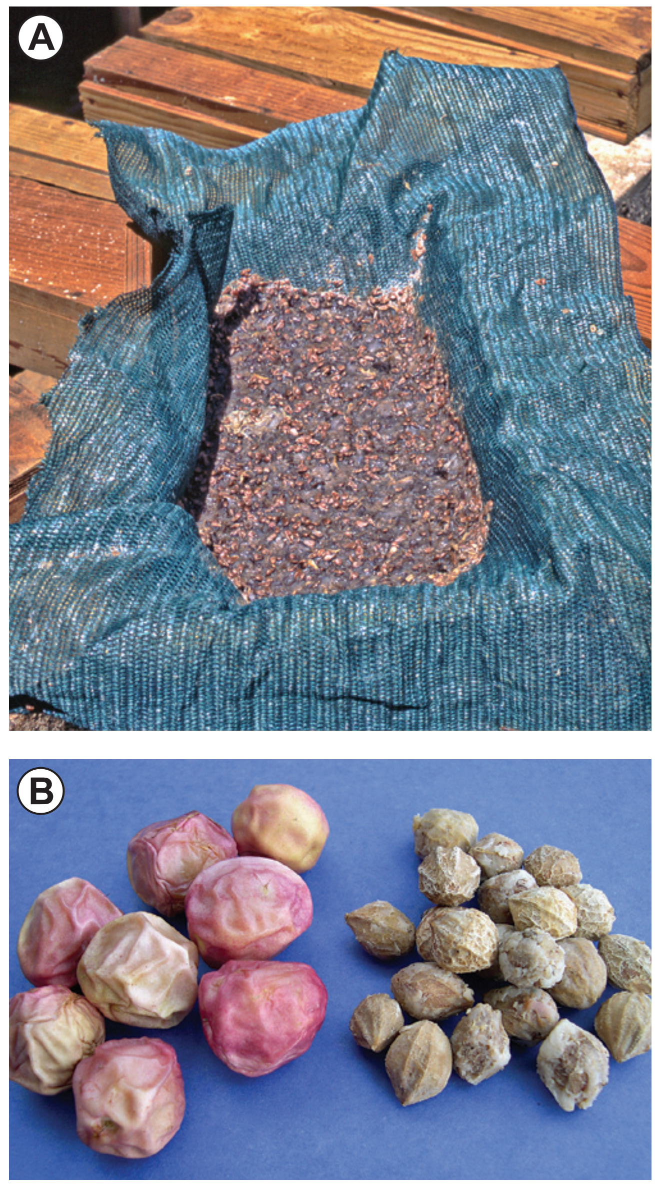


Figure 8.16—*Easily clean fleshy fruits by using a simple mesh cloth and running water to remove pulp from seeds (A). Ripe fruit from coco plum or icaco (*Chrysobalanus icaco*), a coastal shrub native to Puerto Rico and the U.S. Virgin Islands, has the stringy flesh removed, leaving cleaned seeds ready for storage (B). Photo A by Thomas D. Landis, and photo B by Brian F. Daley.*

Figure 8.17—*Modifying kitchen blender blades by using rubber coating allows the grower to clean small lots of dry and fleshy fruits without damaging the seeds. Photo by R. Kasten Dumroese.*

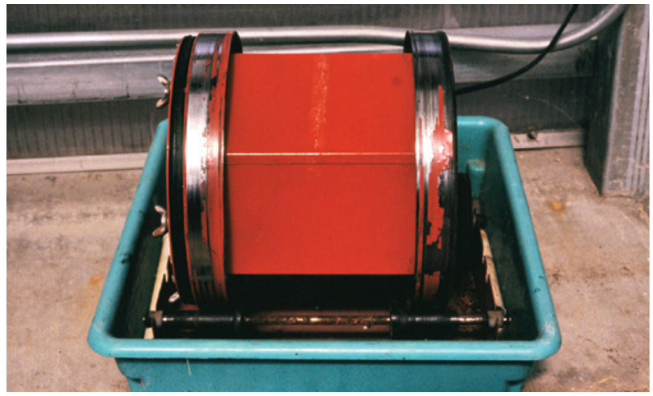


Figure 8.18—*A small hobby-size rock tumbler can be used to clean dry fruits with hard-to-remove appendages or fleshy fruits. Photos by Tara Luna.*

rubber-lined tumbler vessel. Add only enough water to make a slurry from the gravel and fruit. The tumbler can be run overnight and checked the following day. After a course of tumbling, the contents are dumped into a sieve and the pulp or debris is washed off, leaving clean seeds (Dreesen 2004).

If fleshy fruits of species with dormant seeds are being cleaned, they need to be washed with water to remove any remaining pulp and dried for several days before storage.

Seed Testing

After seeds are cleaned, it is a good idea to determine their quality by testing seed viability, seed germination, or both. Seed viability tests estimate the potential for seeds to germinate and grow, whereas seed germination tests measure the actual germination percentage and rate. For seeds you are purchasing or selling commercially, you may also want to know the percentage of pure live seeds (PLS.)

Seed Viability Tests

Cutting tests, described previously, are the simplest seed viability tests and are usually performed during seed collection and often just before treating seeds for sowing. Cutting tests should also be performed on seedlots that have been stored for a long time to visually assess their condition. Cutting tests can reveal whether or not the seed is healthy, but really cannot determine anything about the potential for germination. A better test is the tetrazolium (TZ) test, a biochemical method in which seed viability is determined by a color change that occurs when particular seed enzymes react with a solution of triphenyltetrazolium chloride. Living tissue changes to red, while nonliving tissue remains uncolored (figure 8.19). The reaction takes place both with dormant and nondormant seeds, and results can be obtained within a couple of hours. Although the TZ test is easy to do, interpretation of results requires experience. For this reason, some larger nurseries or nurseries that also sell seeds send seed samples to seed analysts that have the necessary laboratory equipment and experience for testing. A third test is an excised embryo test. Embryos are carefully removed from seeds and allowed to grow independent of the seed tissue. Seeds often must be soaked for several days to remove hard seed coats, and excision of the embryo is an exacting procedure that normally requires the aid of a microscope. As when doing TZ testing, most nurseries send their seed samples to seed analysts for excised embryo testing.

Germination Tests

A seed germination test determines both germination rate and total germination percentage, and is used to determine sowing rates so seeds are used efficiently (figure 8.20). The germination rate indicates how promptly seeds germinate, whereas germination percentage indicates what proportion of the seeds eventually germinate. Germination tests are used to determine how many seeds to sow per container and how long you can expect seeds will continue to germinate after sowing. See Chapter 9, Seed Germination and Sowing Options, for details about sowing rates and methods.

Figure 8.19—*Tetrazolium (TZ) tests stain living tissue red and can be used to estimate seed viability of a seedlot. Shown in this figure (left to right): dead embryo, damaged embryo, and healthy seed. From Stein and others (1986).*

Figure 8.20—*Paper towels (A), sterile sand (B), and* Sphagnum *(C) are suitable substrates for germination testing. Photos from Vozzo (2002).*

If the species being tested has some type of seed dormancy, an appropriate treatment to remove dormancy will be needed before the germination test. Many nurseries will test dormant seedlots before and after the dormancy treatment to check its effectiveness. Actual germination in the nursery may vary greatly because of the inherent variability of germination in most plant species and differences in the environmental conditions during testing and growing at the nursery.

Use the following steps to conduct a germination test:

- Select an area in the greenhouse or office that can be kept clean.
- Line the bottom of plastic trays, Petri dishes, or similar containers with paper towels. For large-seeded species, line the bottom with moist sterile sand (bake sand in the oven at 212 °F [100 °C] for at least 1 hour to sterilize it) or unmilled *Sphagnum* moss.
- Moisten the paper towels or other substrate with distilled water.
- Remove equally sized seed samples from each container of the same seedlot, or, if only one container exists from the seedlot, remove the seeds from different portions of the container. Mix these samples together to form a representative sample (figure 8.21).
- From the sample, make 4 replicates of 100 seeds and spread each replicate onto the moist substrate in a container. The containers may be covered to reduce evaporation from the substrate.
- Use distilled water to remoisten the substrate as necessary, but never allow standing water to remain in the container.
- Place the containers under optimum germination conditions—ideally those in which light, temperature, and humidity can be controlled. Conditions similar to the nursery will yield more meaningful results.
- Count the number of germinants on a daily or weekly basis for up to 4 weeks on herbaceous species and up to 3 months on woody species. Uniformity of germination timing may be advantageous, but be sure you do not exclude healthy seeds that simply germinate more slowly from the genetic pool for that species.

Percentage of Pure Live Seed

The percentage of pure live seed (PLS) is a seed quality index that can be calculated during seed testing (figure 8.22). When seeds are bought or sold, it is important to know the seeds have high PLS values and very low percentages of weed seeds and other inert materials. It is often a

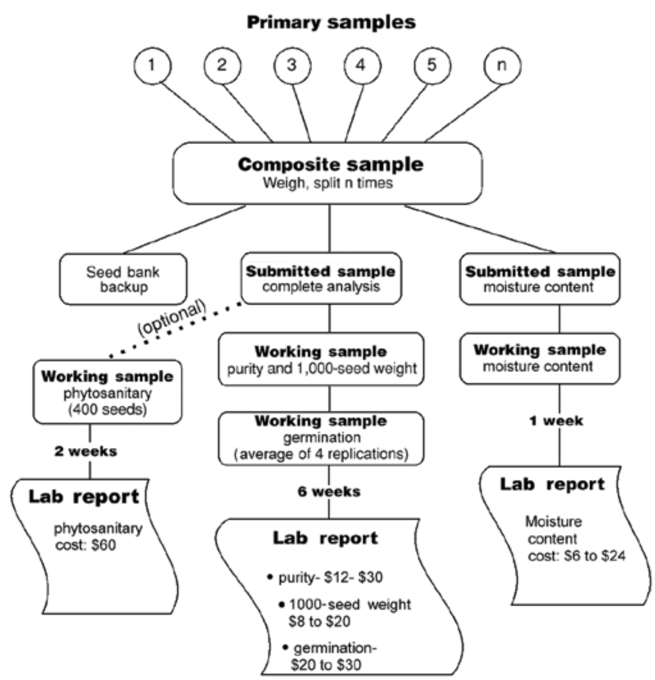


Figure 8.21—*Test seeds by collecting primary samples from an entire seedlot to make up a composite sample. The composite sample is further divided into samples tested at the nursery or submitted to a seed laboratory for testing. Illustration from Dumroese and others (2008).*

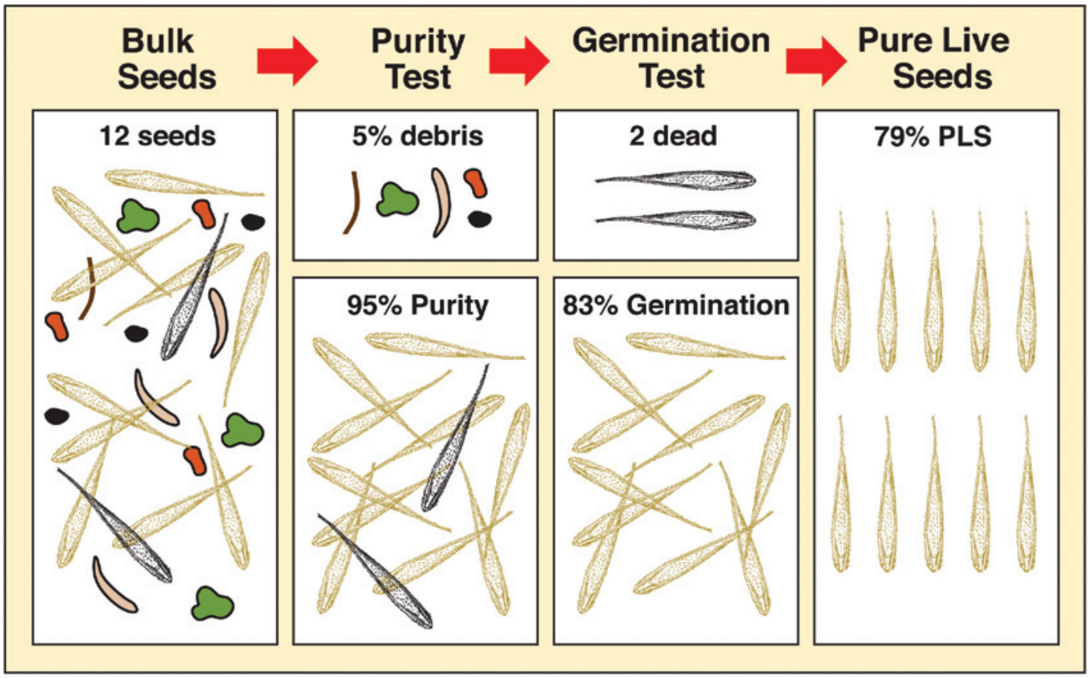


Figure 8.22*—Pure live seeds (PLS) is the percentage of the bulk seed weight that is composed of viable seeds. In this example, results of a purity test show 95 percent of the bulk weight is composed of seeds. The subsequent germination test indicates that 83 percent of the seeds germinated. Multiplying percentage purity by percentage germination yields 79 percent PLS. Illustration from Steinfeld and others (2007).*

good idea to ask about where the seed was collected and to determine what weeds may be present in the seedlot.

Storing Seeds

It can be quite beneficial to store seeds, especially for those species that yield seeds irregularly or to take advantage of a bumper crop of seeds. In addition, long-term seed storage is an important conservation method for threatened and endangered species. For proper seed storage, seeds must be mature and free of mechanical injury. The viability of seeds after storage depends on their viability at harvest, how they were handled during processing before storage, and storage conditions. Even under the best conditions, seeds degrade—the degree of longevity varies by species.

Storage Methods for Recalcitrant Seeds

As previously discussed, recalcitrant seeds of tropical species only retain viability for a short time; they are usually stored only temporarily before sowing. Some nut-bearing species, however, can be stored for a few months as long as seeds retain high moisture content (35 to 50 percent) under high relative humidity with good ventilation at cool temperatures. Recalcitrant seeds need to have constant gas exchange, so they are usually stored in unsealed containers in plastic bags filled with moist peat moss in a cool place, such as in the refrigerator. Ideal temperature for recalcitrant seed storage must be determined on a species-by-species basis.

Because recalcitrant-seeded species are numerous and ecologically important in the tropics, nursery propagation efforts play a key role in conserving and restoring tropical recalcitrant species (Kettle and others 2011).

Storage Methods for Intermediate and Orthodox Seeds

Intermediate seeds can be stored if the proper storage conditions are provided and seeds are dried to the appropriate level of seed moisture content. The ideal seed-moisture content and storage temperature varies among tropical species, however. In general, dried intermediate seeds cannot be stored below 50 °F (10 °C).

In nature, orthodox seeds of most tropical species occur in areas with a distinct wet-dry seasonal cycle, arid beach strands, savannahs, or high-elevation environments (as seen in Hawai'i). For example, under proper storage conditions, the viability of *Acacia koa* seeds remained high after 25 years in storage (Young 1993). Orthodox seeds can be found in many tropical species within several families (Asteraceae, Brassicaceae, Chenopodiaceae, Combretaceae, Cucurbitaceae, Fabaceae, Lamiaceae, Poaceae, Rosaceae, Solanaceae, and Pinaceae). Species that produce achenes, many seeded berries, dry pods, follicles or capsules containing small seeds, or urticles, siliques, caryopses, or schizocarps tend to produce orthodox seeds (Hong and Ellis 1996, Vozzo 2002). Regardless, growers need to test freshly harvested orthodox seeds before long-term storage to develop a baseline germination percent.

After the seeds are clean, air-dry them in shallow trays for 2 to 4 weeks before storage to reduce the moisture content. Stir them once a week or often enough to prevent uneven drying. Storing orthodox seeds requires low relative humidity, low seed-moisture content, and cool temperatures (figure 8.23A). A small change in seed-moisture content has a large effect on the storage life of seeds. With most orthodox species, the proper seed-moisture content for storage is 6 to 10 percent. Small seedlots can be stored in sealed jars with rubber gaskets on the lids or envelopes kept in a sealed, thick-walled plastic tub with an airtight lid (figure 8.23B). Heat-sealed plastic pouches used for food are effective and can be resealed as needed (figure 8.23C). An electronic moisture meter can be used to measure seed-moisture content and is available from several suppliers (figure 8.23D).

Three seed storage methods are used by small tropical nurseries: room temperature storage, refrigeration, and in some rare cases, freezing. If cooler or freezer storage is being used and long power outages could occur, consider using a backup power supply; short-term fluctuations are generally not a problem.

Although orthodox seeds can be stored at room temperature, they will deteriorate faster than those stored at low temperatures. Room temperature storage should only be used when seedlots are held for a short time. Seed moisture content during room storage needs to be at the low end of the range—6 to 8 percent. Seeds must be placed in airtight containers and stored in a room or area with low relative humidity. This storage method works best in the more arid portions of the tropics.

Figure 8.23*—Orthodox seeds need to be properly dried before storage and kept in moisture-proof containers under cool conditions with low humidity, such as in a refrigerator at the Hawai'i Island Seed Bank (A). Each seedlot should be labeled noting origin, date, and the viability percentage. Small lots can be stored in envelopes as long as they are kept in a moisture proof container (B) or in plastic pouches (C). An electronic meter measures temperature and moisture (D). Photos A, C, and D by J.B. Friday, courtesy of Jill Wagner and the Hawai'i Island Seed Bank, and photo B by Tara Luna.*

Orthodox seeds of many tropical species can be stored in a refrigerator at temperatures above freezing. Seeds need to be placed in an airtight container and kept at 38 to 41 °F (3 to 5 °C) in a self-defrosting refrigerator that maintains relative humidity between 10 to 40 percent. If the door is rarely opened, the humidity in a self-defrosting unit will maintain low relative humidity levels.

Very few tropical species will tolerate freezing—for those that do, dry seeds until the seed-moisture content is low and place them in airtight containers. When removing frozen seeds from the freezer, allow the container to reach room temperature before opening it. This practice prevents water condensation from forming on seeds.

Silica gels, available from hobby shops and florists, can be used to maintain low seed-moisture content with seeds that have been properly dried before storage. Silica gels have been used on short-lived native grass seeds placed into long-term storage to enhance longevity and should be tried with other short-lived seeds of native species (Dremann 2003). A general rule is to pour a teaspoon (about 5 ml) of silica gel into a paper envelope and place it with the seeds inside a tightly sealed jar for every 2 ounces (57 g) of seeds that need to be stored. The silica gel will remove water vapor and ensure that seeds remain at the proper storage moisture. To recharge them, the gels can be baked in an oven (150 °F [66 °C]) for 1 hour or so.

Sowing Seeds After Long-term Storage

In some cases, absorbing water too quickly may damage seeds of large-seeded species that have been dried to low-moisture levels. Therefore, when rehydrating these seeds, remove them from storage and spread them evenly in a sealed plastic tub. Place moistened paper towels in the tub so that the towels do not touch the seeds directly. Water vapor released from the towels will be slowly absorbed by the seeds; after a couple of days, the seeds will be able to handle water uptake without injury.

References

Dawson, I.; Were, J. 1997. Collecting germplasm from trees—some guidelines. Agroforestry Today. 9(2): 6–9.

Dremann, C. 2003. Observations on *Bromus carinatus* and *Elymus glaucus* seed storage and longevity. Native Plants Journal 4:61-64.

Dreesen, D. 2004. Tumbling for seed cleaning and conditioning. Native Plants Journal. 5: 52–54.

Dumroese, R.K.; Landis, T.D.; Wenny, D.L. 1998. Raising forest tree seedlings at home: simple methods for growing conifers of the Pacific Northwest from seeds. Moscow, ID: Idaho Forest, Wildlife and Range Experiment Station. 56 p.

Dumroese, R.K.; Luna, T.; Landis, T.D. 2008. Nursery manual for native plants: volume 1, a guide for tribal nurseries. Agriculture

Seeds Are a Link Between the Evolutionary Processes of the Past and the Potential for Future Adaptation

(Adapted from Flores 2002: 14–15)

"The genotype of a tree seed is the result of the evolutionary forces operating on the species for centuries. It is adapted to the present environmental conditions, but not to those of the future, especially when environmental conditions are being drastically modified by accelerated global change...The genetic combinations able to survive through environmental changes have intrinsic value.

Seed germination is influenced by the environmental conditions during seed development and maturation while on the parent tree. Day length, temperature, parental photothermic environment, light quality, and elevation are factors that significantly influence germination capacity. Additional factors include the inflorescence position on the parent tree, seed position in the fruit or infrutescence, and parent tree age during floral induction. These factors, plus others, explain the strong variation found in seed parameters (weight, color, water content, germinabilty) among seed groups and among seeds in the same group.

To most people, the concept of "seed" is deceptively simple. It is compared with a pill, isolated from the environmental effects, replicated many times, and capable of producing a plant. A seed is attached to a long and complex evolutionary and physiological history, however, and it is also conditioned to the variations of a long and complex future. The study of seeds has many facets and should not be limited to collection, storage, and sowing of this year's crop."

Handbook 730. Washington, DC: U.S. Department of Agriculture, Forest Service. 302 p.

Flores, E.M. 2002. Seed biology. In: Vozzo, J.A., ed. The tropical tree seed manual. Agriculture Handbook 721. Washington, DC: U.S. Department of Agriculture, Forest Service. 13–118.

Hong, T.D.; Ellis, R.H. 1996. A protocol to determine seed storage behavior. International Plant Genetic Resources Institute Tech. Bull. No. 1. Rome, Italy: International Plant Genetic Resources Institute.

Kettle, C.J.; Burslem, D.F.R.P.; Ghazoul, J. 2011. An unorthodox approach to forest restoration. Science. 333: 36.

Scianna, J.D. 2004. Blending dry seeds clean. Native Plants Journal. 5: 47–48.

Stein, W.I.; Danielson, R.: Shaw, N.; Wolff, S.; Gerdes, D. 1986. Users guide for seeds of western trees and shrubs. General Technical Report PNW-193. Corvallis, OR: U.S. Department of Agriculture, Pacific Northwest Station. 45 p.

Steinfeld, D.E.; Riley, S.A.; Wilkinson, K.M.; Landis, T.D.; Riley, L.E. 2007. Roadside revegetation: an integrated approach to establishing native plants. Technology Development Report FHWA-WFT/TD-07-005. Vancouver, WA: U.S. Department of Transportation, Federal Highway Administration. 413 p.

Thomas, D. 2003. Modifying blender blades for seed cleaning. Native Plants Journal. 4: 72–73.

Truscott, M. 2004. Cuisinart for cleaning elderberry (*Sambucus* sp. L. [Caprifoliaceae]). Native Plants Journal. 5: 46.

U.S. Department of the Interior, Bureau of Land Management, Seeds of Success[BLM/SOS]. 2011. Technical protocol for the collection, study, and conservation of seeds from native plant species for seeds of success. Native Plant Materials Development Program: 8–11. http://www.nps.gov/plants/sos/training/index.htm. (October 2011).

Vozzo, J.A., ed. 2002. The tropical tree seed manual. Agriculture Handbook 721. Washington, DC: U.S. Department of Agriculture, Forest Service. 899 p.

Withrow-Robinson, B.; Johnson, R. 2006. Selecting native plant materials for restoration projects: insuring local adaptation and maintaining genetic diversity. Corvalis, OR: Oregon State University Extension Service.

Young, Y. 1993. Seeds of the woody plants of North America. Portland, OR: Dioscorides Press. 407 p.

Additional Reading

Landis, T.D.; Tinus, R.W.; Barnett, J.P. 1999. The container tree nursery manual: volume 6, seedling propagation. Agriculture Handbook 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 167 p.

Schmidt, L. 2000. Guide to handling of tropical and subtropical forest seed. Humlebaek, Denmark: Danida Forest Seed Centre. 511 p.