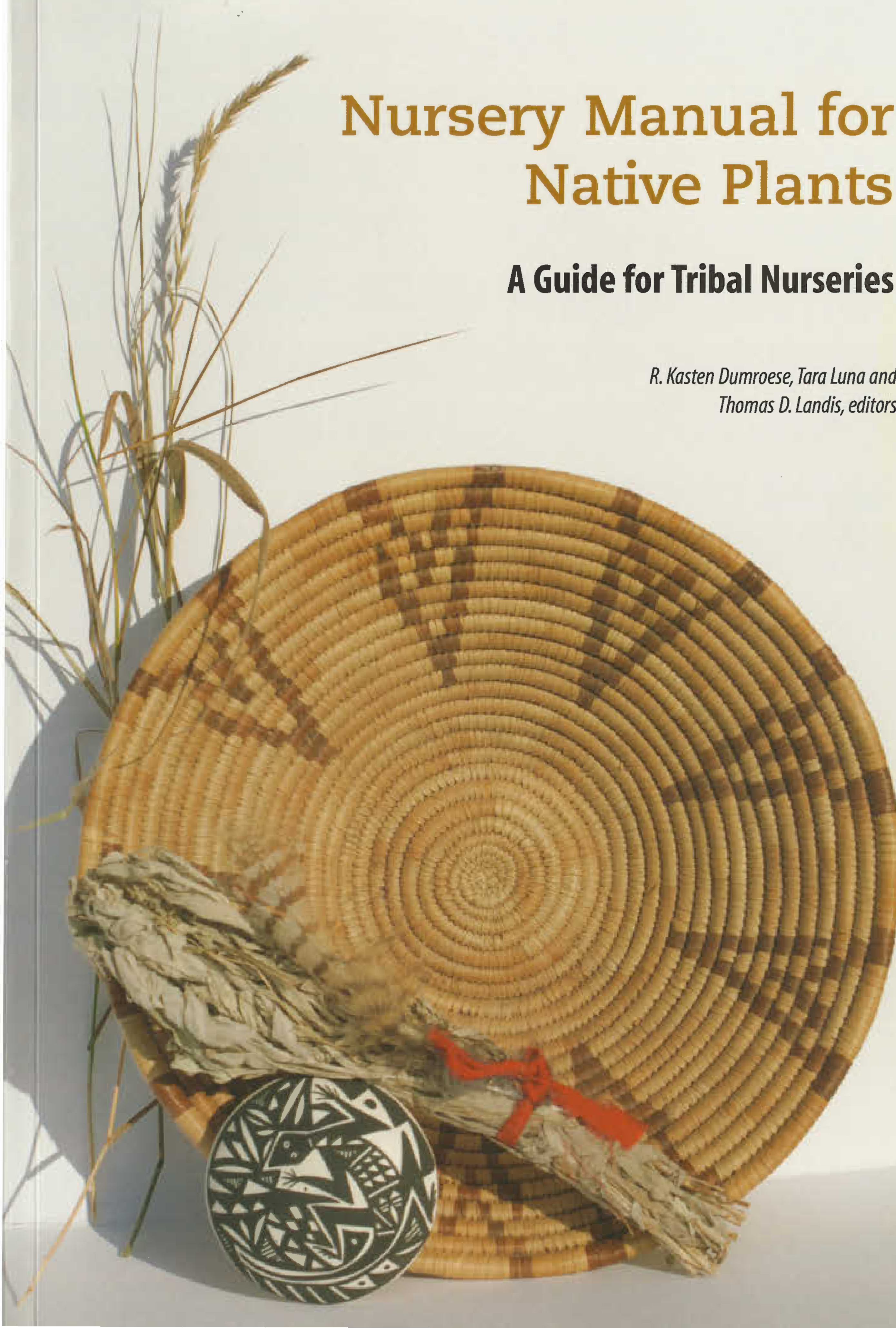
Nursery Manual for Native Plants

A Guide for Tribal Nurseries

R. Kasten Dumroese, Tara Luna and Thomas D. Landis, editors



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Collecting, Processing, and Storing Seeds

7

Tara Luna and Kim M. Wilkinson

Nurseries that work to strengthen and expand the presence of native species are concerned about fostering diverse populations that are strong and well adapted. For many native plants, however, the natural diversity of wild populations has been depleted. Habitat loss has reduced the range and sheer number of plants. For plants with commercial value, unsustainable harvesting practices may have reduced the number of plants with desirable characteristics while leaving behind inferior plants. This process of depleting a population of the best genetic properties so that future populations are weaker than the original is called "genetic degradation." Seed collection for plant propagation is an opportunity to reverse the trends of genetic degradation and species loss. Nurseries have a key role in conserving the gene pool of native plants.

GENETIC DIVERSITY AND SEED COLLECTION ETHICS

Today, seed collection ethics is an important consideration in native plant nurseries, and traditional indigenous practices serve as a valuable model. Collecting from a wide genetic base fosters a more diverse gene pool at the outplanting site. This practice can protect a planting against unforeseen biological and environmental stresses and also protect against inbreeding in future generations. For restoration and conservation projects, maintaining genetic diversity is a key part of project objectives. This important topic will be discussed in greater detail later in this chapter, but the first step is learning more about flowers and seeds.

A variety of dry native fruits and seeds by Tara Luna.

Figure 7.1—*(A) Cones of gymnosperms can be dehiscent at maturity, as seen in Douglas-fir which (B) release winged seeds. (C) Gymnosperm seeds include an embryo, nutritive tissue, and seedcoat.* Photos by Thomas D. Landis, illustration from Dumroese and others (1998).

UNDERSTANDING FLOWERS AND SEEDS

Seed collectors and growers need to be able to identify fruits and seeds to ensure collection of the right structure at the right stage of development. It is not uncommon for novices to collect open fruits after the seeds have dispersed or immature fruits or cones. In some species, what appears to be a seed is actually a thin-walled fruit containing the seed. Furthermore, a collector must be able to recognize mature seeds from immature or nonfilled seeds. Protocols describing flowering, fruits, seeds, and methods of seed collection, processing, and storage can be found in volume 2 of this handbook.

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. For further discussion on fern spore collection, see volume 2 of this handbook.

Seed-bearing plants are classified into two groups, gymnosperms and angiosperms, based on their flower types. 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. Dehiscent cones have scales that open at maturity to release the seeds (figure 7.1A), whereas indehiscent cones rely on animals to pry them open and disperse the seeds. In dehiscent and indehiscent cones, the seeds are usually winged (figure 7.1B). Fleshy cones resemble berries and their seeds lack wings. Gymnosperm seeds include an embryo, nutritive tissue, and seedcoat (figure 7.1C).

Angiosperms bear true flowers, and seeds are enclosed in an ovary that develops and surrounds the seeds after fertilization. Pollen is transferred from the anthers (male reproductive structures) 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. Thus, a fruit is a ripened ovary that develops and surrounds the seed after fertilization. It protects the seed and provides it with nutrition during development and helps with the dispersal of mature seeds. The seed is a ripened ovule consisting of a seedcoat, the nutritive tissue (endosperm), and the embryo, although embryo size varies widely among species (figures 7.2A–C).

Most species of angiosperms have perfect (bisexual) flowers, meaning they contain both the male and female reproductive structures in the same flower (figure 7.3A). Perfect flowers can be showy or very small and inconspicuous. Some species have imperfect flowers, meaning that separate male and female flowers are borne in single-sex flower clusters on the same plant (figure 7.3B). Some species are dioecious, meaning that individual plants are either male or female (figures 7.3C and D). Thus, only the female plants will bear fruits and seeds (figure 7.3E).

Because of the wide variety of flower types, resulting fruits also vary tremendously, and this variety greatly influences how seeds are collected, processed, cleaned, and stored. Dry, dehiscent fruits are those that are woody or papery and split open at maturity. Some examples include capsules (figure 7.4A), legumes or pods (figure 7.4B), and follicles (figure 7.4C). 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. Seeds of these species are surrounded by thin shells that 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 7.5A), schizocarps (figure 7.5B), samaras, and nuts (figure 7.5C). Fleshy fruits are those in which the tissue of the ovary is strongly differentiated. The pericarp is the part of a fruit formed by the ripening of the ovary wall. It is organized into three layers: the skin (exocarp), the often 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 (figure 7.6). Berries contain a fleshy pericarp with many seeds, while drupes have a tough stony endocarp (known as the stone or pit) that encloses only a single seed. Furthermore, some fruits are known as aggregate fruits, which are actually clusters of many fruits that develop from single flowers, each bearing one seed.

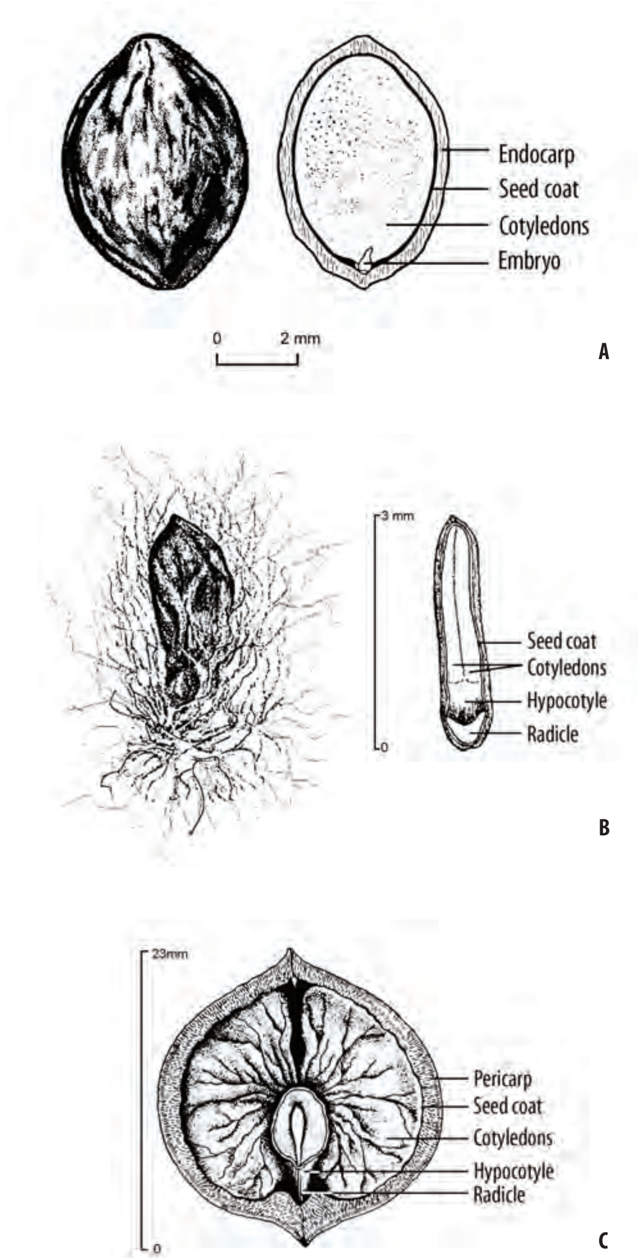

Figure 7.2—*Angiosperm fruits and seeds vary greatly among species: (A) American plum, (B) quaking aspen, and (C) shagbark hickory. In some species, the embryo is not visible to the naked eye.* Illustrations from Schopmeyer (1974).

Figure 7.3—*Examples of flowers: (A) perfect bisexual flower of Woods' rose, (B) imperfect flowers borne in male and female clusters (catkins) on the same plant of paper birch, imperfect dioecious flowers borne on separate plants of willow (C) male flowers, (D) female flowers; (E) mature seed capsules on female plant.* Photos by Tara Luna.

Concerning longevity, seeds can generally be classified into two groups: recalcitrant and orthodox. Recalcitrant seeds retain viability for only a few days, weeks, or months and, generally, for not more than 1 year. Examples include willow, cottonwood, and quaking aspen; nut-bearing trees such as white oaks, black walnut, and pecan; and many aquatic species such as wild rice. In general, large-seeded species that drop moist from perennial plants in habitats that dry out during the season are most likely recalcitrant (Hong and Ellis 1996). Recalcitrant species are usually sown in the nursery immediately after collection.

Orthodox seeds store easily for long periods of time because they tolerate desiccation. Most temperate species fall into this category. Orthodox seeds retain viability for periods longer than a year and they can be dried to low moisture levels and stored under lower temperatures. Species that grow in areas that are seasonally unsuited for germination usually produce orthodox seeds. Dry, hard seedcoats and small seeds from dry, dehiscent fruits are most likely to be orthodox. Medium-lived orthodox seeds remain viable from 2 to 15 years. This category includes many species of trees, shrubs, grasses, and forbs in temperate climates in a wide range of habitats. Long-lived orthodox seeds remain viable for 15 to 25 years or more. This category includes most conifers, shrubs, and legumes and other species that are adapted to fire ecology or desert environments.

COLLECTING SEEDS

Selecting a Proper Seed Source

Using the proper seed source is a key aspect of growing seedlings targeted to the needs of the outplanting site. Adaptation to site conditions, resistance to pests and diseases, desired characteristics of the plant, and growth rate of the plant are additional factors to consider. Ideally, seeds are collected from individuals currently thriving on the outplanting site. If the outplanting site has been heavily degraded, however, this may not be possible. In that case, seeds should be collected from populations similar to those of the outplanting site. Seed collection zones have been developed for some species, primarily commercial forest tree species, in some areas of the country, as described in Chapter 2, *The Target Plant Concept,* but are lacking for most other native plants. When collecting to ensure adaptation to the site, try to find seed sources having similar climate, soil type, elevation, precipitation, and environmental stresses such as wind and drought.

The presence of pests and diseases varies from site to site. Local plants that are thriving are excellent candidates. Plants showing obvious pest or disease problems may pass on those susceptibilities to their offspring. In addition, plants within a population can vary dramatically in their characteristics, such as the qualities and productivity of their fruit, wood, or medicinal products. Some characteristics may be difficult for seed collectors to discern. Collectors should ask for help from clients to choose parent plants with preferred properties.

Productivity is an important factor for some outplanting projects. For plants with food, wood, fiber, or other uses, high productivity in terms of abundant fruit, nuts, foliage, or fast growth rate for high-quality wood is often desired. Collectors should choose plants with high vigor and health. Many native species produce large seed crops only periodically. In good seed years, seed quality and quantity tends to be high. Heavy seed crops generally occur several years apart, and are often followed by light seed crops the following year. The interval between heavy seed-bearing years is referred to as periodicity.

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.

Finally, the genetic quality of seeds used in the nursery can be a major factor in the success of an outplanting project. Seed selection is definitely an area in which "quality over quantity" should be the standard. Care in selecting seed sources can foster plants that are more productive, better adapted to local site conditions, and better suited to achieve the results planned for the project. The long-term ecological viability and sustainability of a planting is also at stake, because projects should contain enough diversity to reproduce healthy and productive offspring for future generations while remaining resilient to environmental stresses.

Ecology of the Species

To become an efficient seed collector, you need to learn as much as possible about each species. During the first few years, novice seed collectors need to spend as much time in the field as possible and keep good notes (figure 7.7A). Monitoring the development of the seed crop throughout the season 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 the time of flowering for each species. Flowering is easily observed in species with showy flowers but requires more attention for wind-pollinated species such as conifers, grasses, and willows. Most developing fruits become visible only a few weeks after flowering and pollination. Over time, recognizing the flowering sequence of the local flora allows the seed collection schedule to be simplified by keying it to the flowering period of a few index species. Familiarity with the species and local site conditions allows the development of a locale-specific seed collection schedule.

Figure 7.4—*Dry, dehiscent fruits such as (A) capsules (penstemon), (B) legumes or pods (lupine), and (C) follicles (milkweed) should be collected as soon as the sutures along the fruit wall begin to spilt open.* Photos by Tara Luna.

Figure 7.5—*Dry, indehiscent fruits such as (A) achenes (arrowleaf balsamroot), (B) schizocarps (biscuitroot), and (C) nuts (oak) are actually single units in which the fruit walls are fused to the seeds.* Photos by Tara Luna.

Figure 7.6—*Fleshy fruits of native plants, from top left: drupes of chokecherry, berries of snowberry, pomes of Cascade mountain-ash, berries of kinnikinnick and tall huckleberry, aggregate fruits of thimbleberry, berries of serviceberry, and hips of Woods' rose. Center: drupes of redosier dogwood.* Photo by Tara Luna.

Another important factor to consider is that 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 the growing season. Other species, such as redosier dogwood, may produce several distinct fruit crops in a season on individual plants. If broad genetic representation is the collection goal, you will need to collect fruits at several times during the season.

Each species has different types of flower arrangements, which will have different blooming sequences. Within a single plant, there is often a range of fruit maturity stages. For example, species such as lupine 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 to the collection site (figure 7.7B).

Be aware of the dispersal strategy of the species before attempting to collect seeds. Fruits have developed many highly specialized devices that aid in the protection of seeds and the dispersal away from parent plants. Wind dispersal is very common; dispersal units are very small and light or equipped with specially formed devices for flying. Those devices include air-filled cavities, seeds or indehiscent fruits that are completely covered with hair like cotton, and seeds that are equipped with various kinds of wings or parachutes (figure 7.8). Collectors need to time collection before seed dispersal and windy days.

Other species, such as geranium, ceanothus, and lupine, disperse their seeds by force upon maturation. In these cases, you may need to bag the developing fruits with cloth to capture the seeds (figure 7.9). 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 that seeds will be captured when they are dispersed.

Fleshy fruits are sources of food for animals, and collectors need to time their collection before the fruit is consumed. In some cases, it may be necessary to bag or cage fruits or indehiscent cones to obtain seeds. For example, the indehiscent cones of whitebark pine cones depend on birds and squirrels for seed dispersal, so they are caged with mesh wire to prevent animal predation.

Factors Affecting Seed Formation and Collection Timing

Environmental conditions during the growing season can be either beneficial or detrimental to flowering and seed development. Sudden frosts during flowering can eliminate fruit production for that year. Prolonged periods of cool weather will limit pollinator activity that can result in reduced fruit production. Periods of cold rains will also slow the rate of fruit maturation. Drought and high temperatures may promote flowering, but prolonged moisture stress may cause plants to abort developing fruits and seeds. In cases in which fruits do develop, overall seed viability may be low or seeds may be unfilled. For these reasons, perform a cut test on seeds just prior to collection, as discussed in detail in the following section.

Seed maturation is temperature dependent and is therefore affected by elevation, latitude, and aspect. Populations found on open, south-facing slopes will mature sooner than those on protected, north-facing slopes. Low-elevation populations usually mature first, and seed collectors can follow seed maturity upslope 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. Good soil nutrient status at the collection site also promotes good seed production. Locations that recently have been burned are good sources for herbaceous species because the overstory has been removed and a flush of nutrients has been made available to the plants during flowering, fruit, and seed formation. Older, burned areas are good collection sites for shrubs, which will flower and fruit for several years.

Sites intensely browsed by wildlife and livestock are poor choices for seed collection because animals often consume the current season's growth, which limits flowering and seed production. Certain insects and fungi also consume seeds. Fruits or seeds that have small exit holes, are discolored, or are misshaped should be avoided.

Correct timing is the most critical element in seed collection. Effective native seed collection involves a number of steps to ensure that seeds are collected at the right stage. If seeds are collected before they are fully mature, the effort often results in poor seed viability. Because most seeds are disseminated away from the parent plant upon maturation, arriving at the site too late may result

Figure 7.7—*Monitoring the development of fruits and seeds, such as (A) willow, is a necessary part of collecting native plant seeds. Collection should be timed just as the fruits fully mature, (B) as Linda Markins is doing with these panicled bulrush fruits and (C) Alex Gladstone with these rose hips, but before the fruits disseminate away from the plant.* Photo A by Dawn Thomas, B by Terrence Ashley, C by Tara Luna.

Figure 7.8—*Wind-dispersed seeds, like those of eightpetal mountain-avens, can be challenging to collect because they must be gathered when they are fully mature but before the wind blows them away.* Photo by Tara Luna.

Figure 7.9—*Seeds that disseminate by force with explosive capsules, like snowbrush ceanothus, are best collected by tying cheesecloth bags over the developing fruits.* Photo by Tara Luna.

in the loss of seeds for the season. Proper seed collection timing requires the following practices:

- Locate populations of desired species early in the season.
- Monitor potential sites just after flowering when fruits are becoming visible.
- Record the dates of flowering, fruit, and cone formation. Cones are often a 2-year crop, so you can assess cone crop the year prior to 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 prior to collection.
- Collect seeds during dry weather.

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 inspection for mature, abnormal, infested, or empty seeds. Several seeds from several individuals within the population should 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 seedcoat cavity, and for the presence of an embryo. Depending on the 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 seedcoat is soft and the contents are watery and soft, the seed is immature. If the seedcoat is hard and the contents are firm and light tan to white in color, the seed is approaching maturity or is fully mature. Some species can be collected just prior to maturity if the entire inflorescence is cut and the seeds are allowed to cure properly before cleaning. Generally, the optimum time for seed collection is when fruits are splitting open at the top.

Seed Collection Tools

The choice of tools depends on the species to be collected. Select tools that will not damage the plant or the seeds. Some general collection methods include hand picking or hand stripping, 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, hand scythes, and extendible pruning poles for taller trees.
- A hand lens to examine seeds to ensure they are full.
- Safety razor blades or a 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.
- Hand gloves.
- Wooden trays for collecting the 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.

Maintaining Genetic Diversity through the Ethical Harvest of Seeds

To maintain genetic diversity, follow these guidelines:

- Collect seeds from a minimum of 30 individual plants—50 to 100 individuals is better.
- Avoid collecting from single individuals or small populations with fewer than 30 individuals, unless you are propagating a rare species.
- Collect from distant individuals to reduce the chance of collecting only close relatives; however, this may not be possible with species that occur in small patches.
- Collect a few seeds from as many individuals as possible to ensure a good genetic representation of the population.
- As much as possible, collect seeds from habitat similar in elevation, aspect, and soils to that of the outplanting site to ensure genetic adaptation.
- For trees, gather seeds from throughout the canopy.

Some other ethical guidelines and common sense approaches to collecting include these practices:

- Do not collect all the seeds from a site. Suggestions vary, but most state that only 10 to 50 percent of the total seed crop should be collected from each site.
- Leave enough seeds as a food source for animals and to ensure the reproduction of the population.
- Avoid soil disturbance and plant damage while collecting seeds, especially in fragile habitats.
- If possible, allow an area to rest for at least two growing seasons between collections. Keep in mind that longer periods may be needed for some species and locations.
- Be absolutely certain of the identity of species being collected. If in doubt, collect a plant specimen for later identification.
- If avoidable, do not collect from weed-infested areas.
- Collect relatively even amounts from each plant; no single plant should be overrepresented in the collection.

PROCESSING SEEDS

Proper processing of fruits and seeds begins the moment the fruit or seed is removed from the parent plant. Proper processing includes temporary handling from the field to the nursery; temporary storage at the nursery; and prompt and proper seed extraction.

Temporary Handling from Field to Nursery

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 high temperatures.

Temporary Storage at the Nursery

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 placing them in trays under moist burlap or in plastic bags filled with moistened sand or peat moss at cool temperatures. Relative humidity should be maintained at 80 to 90 percent.

Dry Fruits and Cones

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 on a tarp or mesh screen, but the material will need to be turned several times a day. Turning the material prevents it from becoming too hot, drying in an uneven manner, or becoming moldy.

The best way to dry material is to spread the contents evenly on a 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 7.10). Drying racks should be made with mesh screens that allow air movement but prevent seed loss. Different mesh screens will be necessary for different seed sizes. Dry, dehiscent fruits should also be covered with a fine-mesh cloth to prevent the loss of seeds after fruits open. Good air movement, low relative humidity, and temperatures between 65 and 80 °F (18 and 27 °C) promote even drying and eliminate moisture buildup that can cause mold and damaging temperatures. A ventilated greenhouse or storage shed works well for this purpose. Temperature control is very important; you should use a shadecloth to keep temperatures from rising too high. Avoid rewetting dry fruits after collection. Also, make sure to exclude animals from the seed drying area.

Fleshy Fruits and Cones

Fleshy fruits and cones are very susceptible to fermentation and subsequent damaging overheating. On the other hand, it is important not to let the fruits dry out because this can make cleaning 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.

Processing Fruits and Cleaning Seeds

Seed cleaning is necessary before sowing or long-term storage. In some cases, seeds will fail to germinate if they are not removed from the fruits. Seeds of some species germinate more quickly and evenly if they are removed completely from their coverings. For example, Nebraska sedge has shown improved germination by removing the papery sac (perigynia) surrounding the seed (Hoag and others 2001). Germination is often improved if the seeds are extracted from stony endocarps (pits) prior to treatment and sowing.

Most native plant nurseries regularly deal with small seedlots. Seed cleaning and processing can be laborious and time consuming, and specialized cleaning equipment can be expensive. A variety of "low tech" methods and devices are easy to use, cheap, readily available, and work very well with a variety of fruit types. Some are described below. Whichever method of cleaning is chosen, the seed cleaning area of the nursery should 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.

Cleaning Recalcitrant Seeds

Many species that have recalcitrant seeds, such as maple, often can be collected quite cleanly and are sown immediately. Others, such as members of the white oaks, need additional cleaning that is typically accomplished by flotation in water. Immediately after collection, acorns are placed in a bucket of water. Generally, the viable acorns sink whereas the nonviable acorns, trash, and debris float. As a side benefit, the soaking helps keep the acorns hydrated until they are sown. If acorns are collected in very dry conditions, viable acorns may also temporarily float. In this situation, a longer soak duration, perhaps even overnight, may be necessary to allow enough time for good acorns to hydrate and sink. Do a cut test to fine-tune the procedure.

Cleaning Dry Fruits and Cones

Separating seeds from dry, dehiscent fruits (figure 7.4) is usually the easiest cleaning procedure because the fruits split open at maturity. Small lots can be readily cleaned by shaking the fruits inside paper bags so that the seeds fall out; 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 the blender's size, but one-quarter to one-third of the storage capacity of the blender works well (Scianna 2004).

Extracted seeds will be mixed with pitch globules, dry leaves, wings, and small pieces of cones or dry fruits. Screening is the easiest way to separate dry, indehiscent fruits and seeds. Screens can be constructed of hardware cloth and wooden frames. Commercial screens are also available in a range of sizes (figure 7.11). At least two screen sizes 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 trash can be removed. When separating other small-seeded plants, such as sedges, rushes, and some wildflowers, you will need screens with very fine mesh or kitchen sieves to properly separate seeds from other debris. Finally, finer chaff and empty seeds can be further removed by placing them in front of a fan on a low setting or running them through a series of fine kitchen sieves.

Larger quantities of dry fruits can be cleaned with a variety of commercial equipment, such as hammermills, clippers, dewingers, specific gravity separators, and air separators. The equipment of choice depends on the seeds being cleaned, the amount of debris in the collection, and the desired purity (cleanliness) requirements of the seedlot. A hammermill uses rotating hammers and stationary anvils to smash, crush, and tear dry fruits into smaller fragments to extract the seeds (figure 7.12A). Clippers are used to remove appendages and hulls from seeds and to separate out larger chaff material (figure 7.12B). Dewingers are used to remove winged appendages from seeds and fruits and are most commonly used with conifer seeds.

Conifer cones, after the scales open, can be resacked and shaken by hand or tumbled in a wire cage to dislodge additional seeds from the cone scales. Serotinous cones, such as jack pine or lodgepole pine, require exposure to heat before the scales open. Cones need to be exposed to 170 °F (77 °C) temperatures either by placing the cones in ovens for a period of a few minutes to a few hours or 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

Figure 7.10—*Dry seeds require good ventilation to prevent mold development during post harvest handling and drying.*
Photo by Dawn Thomas.

Figure 7.11—*Screens are used to separate large debris, seeds, and fine chaff from the seedlot and are available commercially in a wide range of screen holes sizes to complement any species.* Photo by Tara Luna.

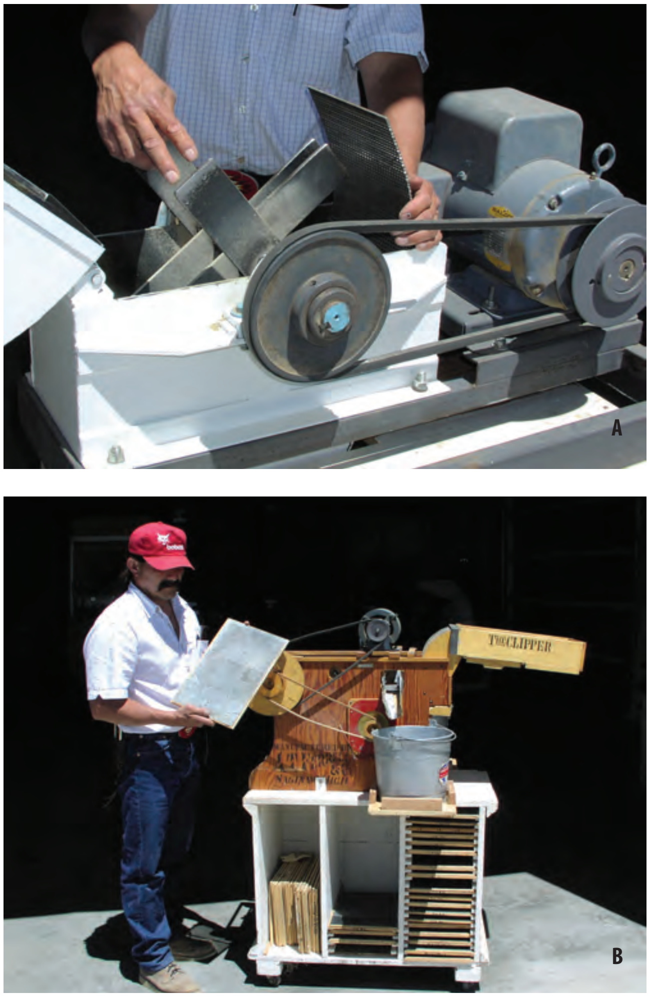

Figure 7.12—*Commercial seed cleaners such as (A) a hammermill or (B) clipper s are useful for cleaning large lots of native seeds.* Photos by J. Chris Hoag.

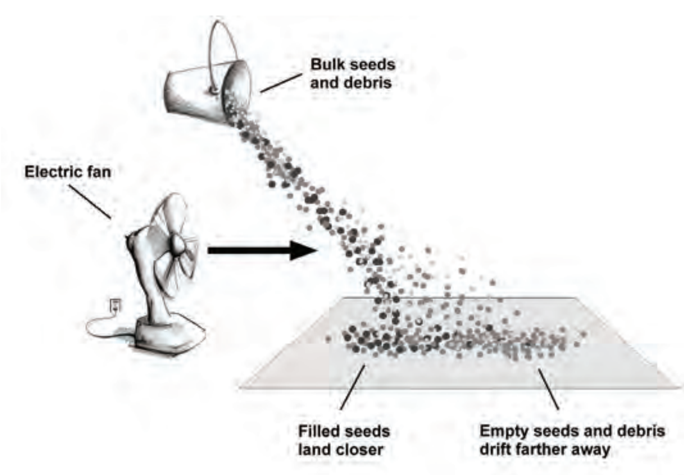

Figure 7.13—*Use a small fan to winnow empty seeds and wings from filled seeds. The heavier filled seeds will land closer to the fan while lighter empty seeds and wings will land farther way.* Illustration from Dumroese and others (1998).

dipped in hot water, the combination of heat and drying after the soak should be sufficient to open them. Seeds can then be removed from cones as described previously. Most conifer seeds are dewinged before sowing and this 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. Friction between the seeds and between the seeds and burlap will detach the wings. Remember to knead slowly and gently because too much friction might damage the seeds. This process requires only a few minutes. A few species, such as western redcedar, longleaf pine, and firs, have very tight wings that should be left on the seeds. Repeat the screening process again with a mesh size that retains seeds but allows the smallest debris to pass through (Dumroese and others 1998). Large seedlots are probably best processed by seed companies.

The last step is fanning or winnowing, which separates detached wings, hollow seeds, and seed-sized impurities from good seeds. The most efficient, high-tech, method is using an agricultural seed cleaning or fanning mill, but these machines require careful adjustment for each species to prevent retaining too many impurities or blowing away too many sound (full) seeds. Another method that works well is winnowing in front of a fan (figure 7.13). When seeds are poured slowly in front of a small electric fan, they separate according to weight from the base of the fan. Most heavy, sound seeds will come to rest near the base of the fan, and 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 the desired degree of seed purity. A good target for most species is 90 percent or more sound seeds (Dumroese and others 1998).

Cleaning Fleshy Fruits and Cones

Seeds in fleshy fruits should be processed soon after collection to avoid fermentation, mummification, excessive heating, or microbial infestation; all of which can damage seeds. 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 should 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. Kitchen food processors and blenders with modified rubber-coated blades can be used for small lots of fleshy fruits. With both devices, run them for a minute or so to produce a puree of fruit and seeds. The puree should be placed in a bucket and water added slowly; viable seeds will sink and debris, including hollow seeds, will float to the surface. By slowly and continually adding water, most of the debris will float off, leaving clean seeds at the bottom of the bucket (Truscott 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. Remember that the way in which seeds and fruits are handled during collection, temporary storage, postharvest handling, and cleaning can directly affect seed quality and viability, as well as seed storage life.

Cleaning Tools for Fleshy and Dry Fruits

Small, hobby-size rock tumblers are useful for dry, indehiscent fruits; rehydrating and cleaning fleshy fruits; or removing barbs or other appendages from seeds and fruits. Wet tumbling uses pea gravel or crushed stones and water in a rubber-lined tumbler vessel. Add just enough water so that the gravel and fruit makes a slurry. 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) (figure 7.14). Another useful tool is the common kitchen blender with modified blades. 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 handtool handles) to prevent damage to the seeds (figure 7.15) (Thomas 2003).

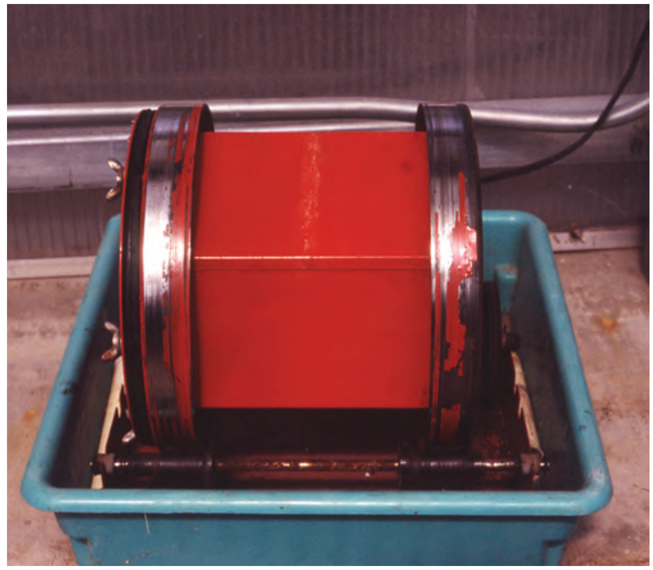

Figure 7.14—*A small hobby-size rock tumbler can be used to clean dry fruits with hard-to-remove appendages or fleshy fruits.* Photo by Tara Luna.

Figure 7.15—*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.

Testing Cleaned Seeds

After the seeds are cleaned, it is a good idea to determine the quality of the seeds by testing seed viability, seed germination, or both. Seed viability and seed germination do not mean the same thing and growers need to know the difference between them. Seed viability tests estimate the potential for seeds to germinate and grow, whereas seed germination tests measure the actual germination percentage and rate. A seed germination test allows you to know the rate and percent germination to expect and thereby determine sowing rates so that seeds are used efficiently.

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 done on seedlots that have been stored for a long period of time to visu-

Figure 7.16—*Tetrazolium (TZ) tests stain living tissue red and can be used to estimate seed viability of a seedlot. Shown here is noble fir (left to right): dead embryo, damaged embryo, healthy seed.* From Stein and others (1986).

ally assess their condition. Cutting tests can reveal whether or not the seed is healthy, but really cannot tell 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 7.16). The reaction takes place with dormant and nondormant seeds and results can be obtained within a couple of hours. Although the TZ test is easy to do, the interpretation of results requires experience. For this reason, most nurseries send their seed samples to seed analysts that have the necessary laboratory equipment and experience for testing. A third viability test is an excised embryo test. Embryos are carefully removed from seeds and allowed to grow independently of the seed tissue. Seeds often must be soaked for several days to remove hard seedcoats, 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

Seed germination tests are regularly done by nurseries to determine seed sowing rates. 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. Testing measures the germination rate and percentage. The germination rate indicates how promptly seeds germinate, whereas the germination percentage indicates how many seeds germinate. Knowing the germination percentage is important for determining how many seeds to sow per container, and knowing the germination rate (speed) provides information on how long seeds will continue to germinate after sowing. See Chapter 8, *Seed Germination and Sowing Options*, for details about sowing rates and methods. Germination tests reflect the potential of a seed to germinate and actual germination in the nursery may vary greatly. This difference occurs because of the inherent variability of germination in most native species and also because of 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 an oven at 212 °F (100 °C) for at least 1 hour to sterilize it) or unmilled *Sphagnum* peat moss. Moisten the paper towels or other substrate with distilled water.
- Remove equally sized samples from each bag of the same seedlot, or, if there is only one container of the seedlot, from different portions of the container. Mix these samples together to form a representative sample (figure 7.17).
- Make four replicates of 100 seeds each and place them on the moist substrate in the 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 weekly basis for up to 4 weeks on herbaceous species and up to 3 months on woody species. Seed treatments that yield a high percentage of germination promptly are the best.

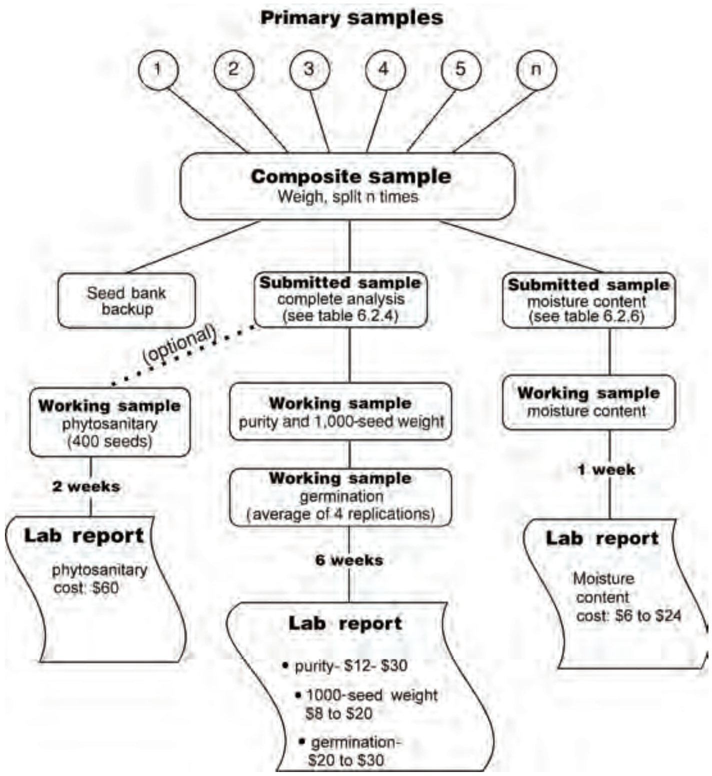

Figure 7.17—*Seeds cans be tested by collecting primary samples from an entire seedlot to make up a composite sample. The composite sample is further divided into samples tested at the nursery or submitted to a seed laboratory for testing.* Illustration by Jim Marin.

Purchasing Seeds from a Reputable Source

Knowing the original collection source of seeds is crucial to ensure that locally adapted, genetically appropriate materials are used. For example, some species, such as yarrow and prairie Junegrass, are native throughout the northern hemisphere so seeds from across the continent, or from Europe, are commonly sold. However, within each species are genetic variations; local populations have adapted to local climate, soils, and other site conditions. Local plant materials, collected from the same or similar area as the outplanting site, have been shown to perform better than non-local sources. Using locally-adapted seed sources is a key factor in ensuring the survival of the plants as well as the protection of local genetic resources. For some species, transfer guidelines may exist. For other species, people 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).

Seed companies may collect seeds to order based on customer needs. If not, it is best to ask what sources the company has, rather than asking for a particular source—unscrupulous dealers may claim to have exactly what you want. Seeds must be 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 and cultivated variety (if applicable). It is also important to obtain information on the origin of the seeds; an estimate of viability; the percentage of pure live seeds (PLS); and the percentage of other crop seeds, weed seeds, and inert material.

Native cultivated varieties are available for some native grasses and forbs and are shown on the tag following the scientific name as a "named" variety. Cultivars are developed by selecting individual plants that undergo further selection for traits that allow for economical seed production. Cultivated varieties are typically used when wild sources are unavailable or when large quantities of seeds are needed for a restoration project.

The germination percentage reflects the germination potential of the seeds at a particular point in time. This potential is usually described as the percentage of 100 seeds that germinate between 0 and 28 days. Many native species, however, do not germinate within that timeframe. Instead, they are tested with dye (TZ) to determine the amount of living seeds. Often, seed distributors will provide a TZ estimate of viability instead of a germination percentage.

The percentage of PLS is a seed quality index that is calculated during seed testing (figure 7.18). PLS is a basis for

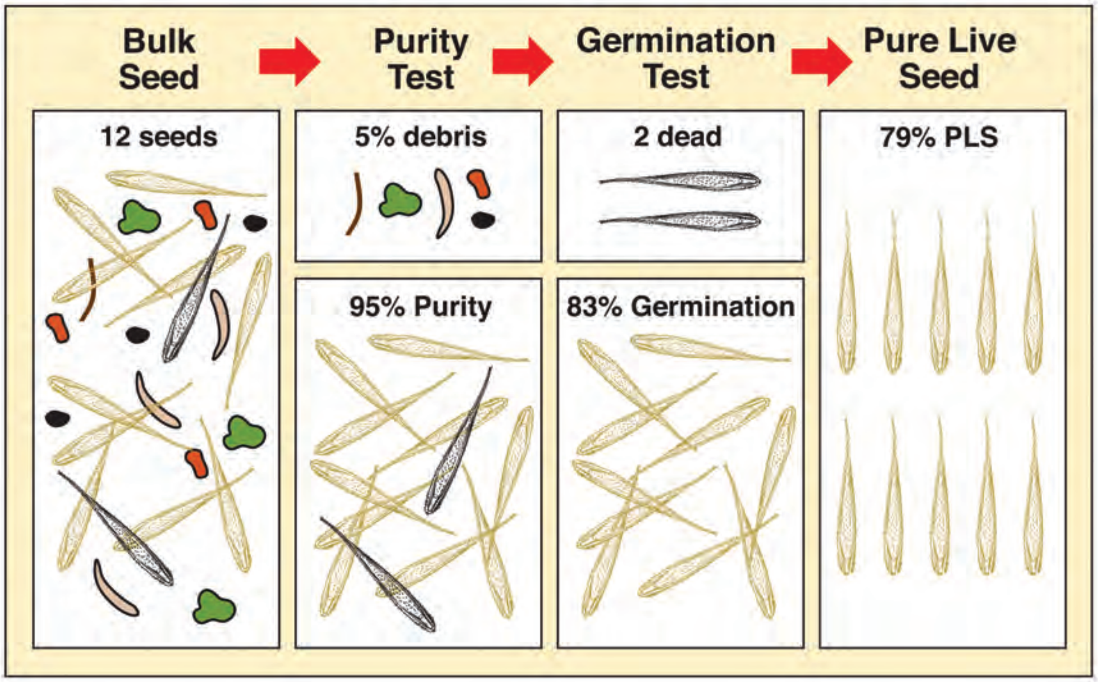

Figure 7.18—*Pure live seeds (PLS) is the percentage of the bulk seed weight that is composed of viable seeds. In this example, results of a purity test show 95 percent of the bulk weight is composed of seeds. The subsequent germination test indicates that 83 percent of the seeds germinated. Multiplying percentage purity by percentage germination yields 79 percent PLS.* Illustration from Steinfeld and others (2007).

comparing seedlots that differ in purity (the percentage of clean seeds) and viability. Purchase only seeds with high PLS values and with very low percentages of weed seeds and other inert materials. It is often a good idea to ask about where the species was grown or collected to determine what weeds may be present in the seedlot.

Avoid purchasing generic wildflower seed mixtures. Often, these mixes include species that were originally native to another portion of the country or are foreign, nonnative species. Some species are aggressive and can displace native plant populations, and some mixes may contain noxious weeds. Purchase wildflower seed mixes only from reputable seed dealers that can provide the exact species composition with locally adapted seed sources.

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, and storage conditions. Even under the best conditions, seeds degrade—the degree of longevity varies by species.

As previously discussed, recalcitrant seeds retain viability for only a few days or, at most, a year; they are usually stored only temporarily before sowing. Some 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 conditions and are exposed to good air movement (stored in unsealed containers) and cool temperatures.

In nature, orthodox seeds of most conifers and hardwood trees usually survive less than 3 years. Under proper storage conditions, however, they may retain high viability after 25 years in storage (Landis and others 1999). Many hard-seeded species, such as lupine and American lotus, can remain viable under artificial storage conditions for even longer periods of time.

Storing orthodox seeds requires three basic principles: low relative humidity, low seed moisture content, and cool temperatures. These principles have been used for thousands of years. Indeed, the domestication of New World crops, such as corn, beans, and squash, by indigenous farmers was in part due to the storability of seeds (figures 7.19A and B).

The two most important factors affecting orthodox seed longevity under storage conditions are seed moisture content and temperature. A small change in seed moisture content has a large effect on the storage life of seeds. Therefore, it is important to know the moisture content to predict the possible storage life of a seedlot. With most orthodox species, the proper seed moisture content for storage is generally between 6 and 10 percent. An electronic moisture meter can be used to measure seed moisture content and is available from several suppliers.

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. Put the seeds in an airtight container and label it well. Most species can be stored at temperatures slightly below to above freezing with good, long-term storage results.

Use the following guidelines to properly store orthodox seeds:

- Maintain low relative humidity and low temperatures in the storage environment to maximize the storage life of the seeds (figure 7.20A).
- Because relative humidity increases with a decrease in temperature, reduce relative humidity in the storage environment so dried seeds do not uptake additional moisture. For a small nursery, self-defrosting refrigerator will provide good results as long as the refrigerator is not used for other purposes.
- Use moisture-proof containers to maintain the proper seed moisture level. Small seedlots can be stored using sealed jars with rubber gaskets on the lids or envelopes kept in a sealed, thick-walled plastic tub with an airtight lid (figure 7.20B). Heat-sealed foil-lined plastic pouches used for food are effective and can be sealed and resealed with an ordinary clothes iron.

Storage Methods for Orthodox Seeds

Three methods of storage are used by small nurseries: freezer, cooler, and room temperature-low humidity storage. If freezer or cooler storage is being used and long power outages could occur, consider using a backup power supply; short-term fluctuations are generally not a problem. Storing seeds in a frozen condition is usually best for long-term storage. Most seeds of temperate species can be stored at temperatures at or slightly below freezing, although many species can be stored at 0 to -5 °F (-18 to -21 °C) in a small household freezer. Seeds are prepared by drying to low levels of seed moisture content. Seeds can be damaged by freezing if the seed moisture content is very high. Be sure to store seeds 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 the seeds.

Some species will not tolerate freezing and can be cold-stored in a refrigerator. Seeds should be placed in an airtight container and kept at 38 to 41 °F (3 to 5 °C); use a self-defrosting refrigerator that maintains relative humidity between 10 and 40 percent. If the door is rarely opened, the humidity in a self-defrosting unit will maintain low relative humidity levels.

Figure 7.19— *The basic principles of seed storage, keeping seeds with low moisture contents stored in airtight containers at low relative humidity, has remained unchanged for thousands of years. (A)The indigenous farmers of the Southwestern United States practiced and continue to practice these techniques successfully to perpetuate many indigenous varieties of crops and native plants. (B) The domestication of New World crops such as corn was in part due to the storability of seeds.* Photos by Richard Hannan.

Figure 7.20—*(A) Orthodox seeds should be properly dried before storage and kept in moisture-proof containers under cool conditions with low humidity. (B) 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).* Photo A by R. Kasten Dumroese, B by Tara Luna.

Although orthodox seeds can be stored at room temperature as well, they will deteriorate faster than those stored at lower temperatures. Ideally, room temperature storage should be used only on seedlots that are held for a short time. The seed moisture content at the time of storage should 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 country.

Silica gels, available from hobby shops and florists, can be used to maintain low seed moisture content. They 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 native species (Dremann 2003). A good rule of thumb is to pour about a teaspoon (about 5 ml) of silica gel into a paper envelope and place it 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 an hour or so.

Storage Methods for Recalcitrant Seeds

Some nut- and acorn-bearing species can be stored for several months as long as the seeds have high seed moisture content (35 to 50 percent) and are stored under cool and moist conditions. Nondormant seeds need to have constant gas exchange, so they are usually stored in unsealed containers in plastic bags filled with moist peat moss in the refrigerator.

Sowing Seeds after Long-Term Storage

In some cases, seeds of large-seeded species that have been dried to low moisture levels may be damaged by absorbing water too quickly. 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.

SUMMARY

Most native plant species are propagated by seeds to preserve wide genetic variability that is needed for successful seedling establishment and survival in the natural environment. Growers must become familiar with the type of fruits and seeds they plan to collect and propagate: they should know the species. Seed source is critical because it affects seedling growth in the nursery and also is important to the adaptability of the seedling to the outplanting site. Maintaining genetic diversity using proper, ethical collection techniques is very important. The manner in which seeds are handled during collection and postharvest handling and cleaning can greatly affect their viability. Seeds of some species are inherently short lived and cannot be stored for periods longer than a few months. Most temperate species, however, have orthodox seeds and can be successfully stored if optimum conditions are provided. Seed quality and testing are necessary to plan and produce a high-quality seedling crop in a timely manner.

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APPENDIX 7.A. PLANTS MENTIONED IN THIS CHAPTER

American lotus, *Nelumbo lutea*
American plum, *Prunus americana*
arrowleaf balsamroot, *Balsamorhiza sagittata*
biscuitroot, *Lomatium* species
black walnut, *Juglans nigra*
Cascade mountain-ash, *Sorbus scopulina*
ceanothus, *Ceanothus* species
chokecherry, *Prunus virginiana*
cottonwood, *Populus* species
Douglas-fir, *Pseudotsuga menziesii*
eightpetal mountain-avens, *Dryas octopetala*
fir, *Abies* species
geranium, *Geranium* species
jack pine, *Pinus banksiana*
kinnikinnick, *Arctostaphylos uva-ursi*
lodgepole pine, *Pinus contorta*
longleaf pine, *Pinus palustris*
lupine, *Lupinus* species
maple, *Acer* species
milkweed, *Asclepias* species
Nebraska sedge, *Carex nebrascensis*
noble fir, *Abies procera*
oaks, *Quercus* species
panicled bulrush, *Scirpus microcarpus*
paper birch, *Betula papyrifera*
pecan, *Carya illinoinensis*
penstemon, *Penstemon* species
prairie Junegrass, *Koeleria macrantha*
quaking aspen, *Populus tremuloides*
redosier dogwood, *Cornus sericea*
rose, *Rosa* species
serviceberry, *Amelanchier alnifolia*
shagbark hickory, *Carya ovata*
snowberry, *Symphoricarpos albus*
snowbrush ceanothus, *Ceanothus velutinus*
tall huckleberry, *Vaccinium membranaceum*
thimbleberry, *Rubus parviflorus*
western redcedar, *Thuja plicata*
white oaks, *Quercus* species
whitebark pine, *Pinus albicaulis*
wild rice, *Zizania palustris*
willow, *Salix* species
Woods' rose, *Rosa woodsii*
yarrow, *Achillea millefolium*