Defining the Target Plant

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People planting native and traditional species in the tropics have diverse goals and face a multitude of challenges on their outplanting sites. Understanding these goals and challenges and the steps necessary to meet them is essential to outplanting success. The Target Plant Concept is used to define what plant materials to grow in the nursery to meet the needs on the outplanting sites and achieve project objectives. A "one-size-fits-all" approach to plant materials does not work well. Instead, plant materials must be matched to meet the challenges of the outplanting site. Establishing targets is critical; for a given species, the target plant destined for a harsh restoration site where care will be minimal after outplanting is very different from one that will be outplanted in a city park or hotel landscape where it will be pampered. Thus, the definition of the target plant depends on how it will be used—its "fitness for purpose" (Sutton 1980). This definition is the essence of the Target Plant Concept.

The Target Plant Concept was developed as a way to define the target plant, and it has two equally important components. The first component incorporates three simple approaches that provide the broad, fundamental basis necessary to successfully complete outplanting projects (figure 3.1). The second component is the step-by-step process of defining the target plant material. The nursery manager and client systematically answer eight sequential, but interrelated questions about the outplanting site and project goals to ultimately define the target plant material. The target plants are then produced, outplanted, and monitored; then the cycle repeats. An understanding of the Target Plant Concept is vital when starting a new nursery or upgrading an existing one and is also useful when working with customers. Let us examine the first of the two components in detail.

Facing Page: *The "target plant" is cultivated to meet the challenges of the outplanting site and the objectives of the project. Photo by J.B. Friday.*

Important Approaches for Implementing the Target Plant Concept

The first component of the Target Plant Concept incorporates three simple, often overlooked ideas that, when considered together, guide the broad approach for defining and selecting the target plant materials for a specific site.

Start at the Outplanting Site

With the Target Plant Concept, the nursery production process starts with the characteristics of the outplanting site. Land managers specify exactly what type of plant material would be best for their site conditions (figure 3.2). Understanding these needs, the nursery grows plant materials that are locally adapted, genetically appropriate, and the optimal size, age, and so on to survive and thrive on the outplanting site.

Forge a Nursery-Client Partnership

With the Target Plant Concept, the land manager and nursery manager work together to define the ideal type of plant for the project, the nursery grows the plants, and they are outplanted (figure 3.3). Based on performance after outplanting, the land manager and nursery manager may work together to revise target plant characteristics to improve survival and growth of future crops (figure 3.4). See Chapter 18, Working With People, for information on how to facilitate meaningful, mutually supportive dialogue after outplanting. Good communication between native plant customers and nursery managers builds partnerships and ensures the best possible plants for the project. This feedback also ensures that both nurseries and clients are learning and adapting, thereby improving successes over time.

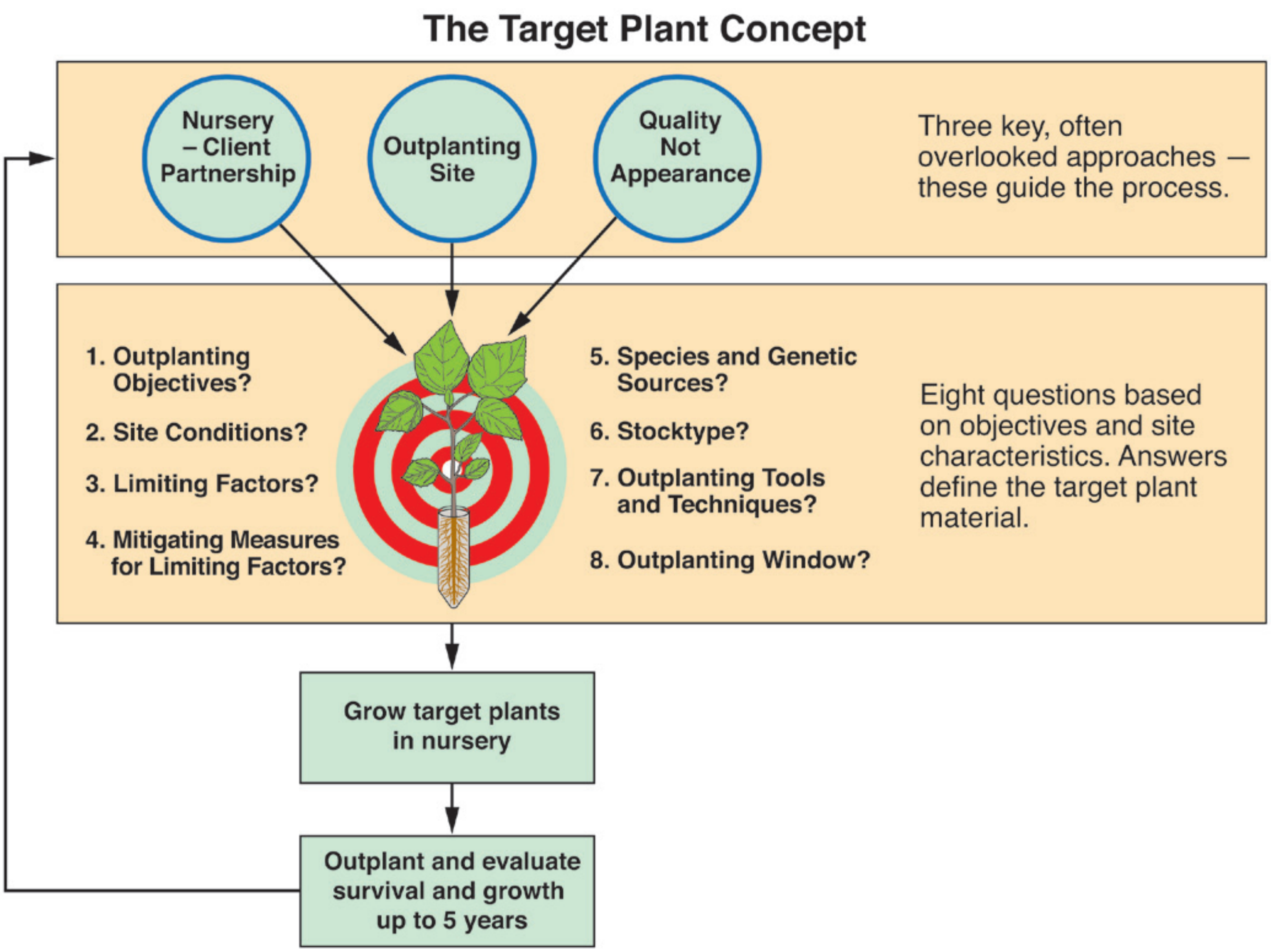

Figure 3.1—The Target Plant Concept starts with a partnership between the client and nursery manager that focuses on putting the best plant materials on specific project sites. The manager and client then answer eight questions about the project; their answers define the target plant material necessary to meet the objectives of that project. The nursery produces the plants. The client and manager subsequently reassess successes and failures and use that information to improve the next crop. Adapted from Landis (2011).

Figure 3.2—Plant materials must be matched to meet the challenges of the outplanting sites and the goals of the projects they serve. A nursery in East Timor grows agroforestry species in polyethylene bags to serve village needs (A). The Palau Municipal Nursery grows native and culturally important seedlings in large pots for urban forestry projects (B). Future Forests Nursery in Hawaiʻi grows native trees and shrubs in several types of containers and growing environments for diverse restoration and farm forestry projects (C). Photo A by J.B. Friday, photo B by Katie Friday, and photo C by Jill Wagner.

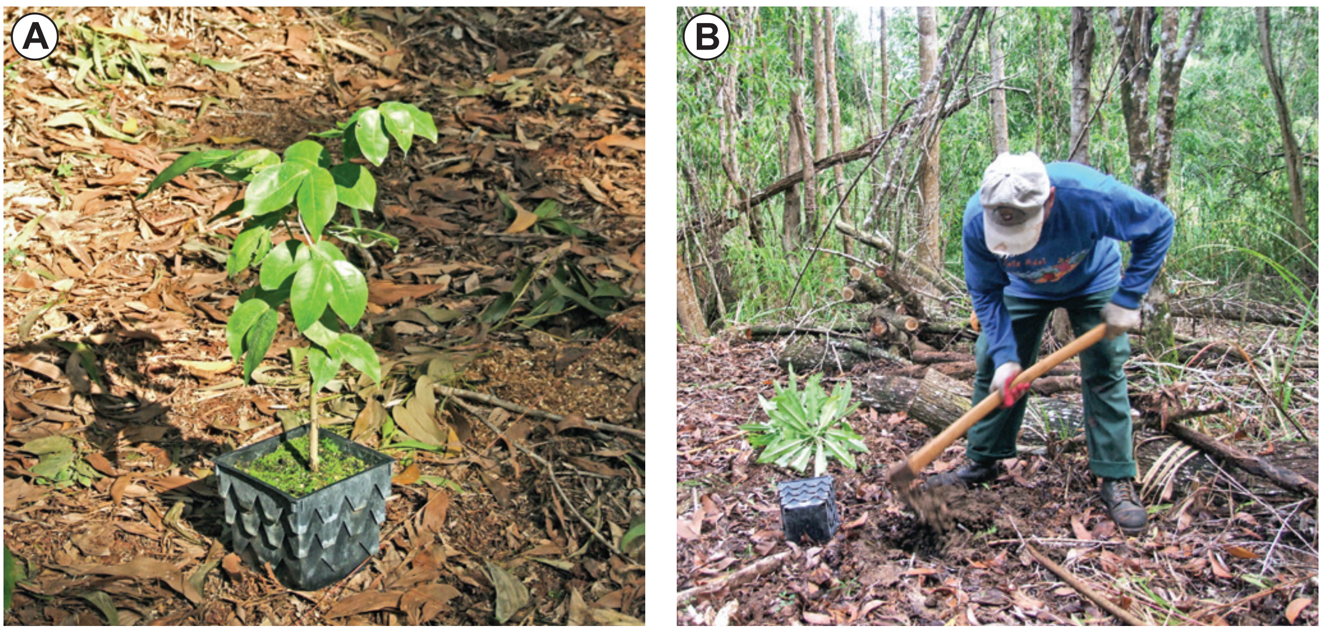

Figure 3.3—Using the Target Plant Concept, nursery and land managers work together to specify what type of plant material would be best suited for the project. Shown is a native reforestation project in Guam, where target plants included native trees such as Intsia bijuga grown in large, 1-gallon root-training square containers (A). The native seedlings were planted using a mattock in soft clay soil (B). Photos by J.B. Friday.

Figure 3.4—Using the Target Plant Concept, the land owner and nursery manager work together to define the ideal type of plant for the project. Based on performance of the first crop, the managers make necessary changes to improve survival and growth. Here a nursery manager and land owner are standing in a 1-year-old mixed forest planting (foreground) and discussing performance of a 4-year-old planting (background) to make some decisions together about next year's target plants. Photo by Craig R. Elevitch.

Emphasize Seedling Quality, Not Appearance

With the Target Plant Concept, plant quality is not determined by how good a plant looks as it sits in the nursery, but by outplanting performance. A beautiful crop of plants in the nursery may perform miserably if the plants are inappropriate for conditions on the outplanting site. Without the Target Plant Concept, inexperienced clients may believe they can find cheap, all-purpose native plants that will thrive nearly anywhere. Using the Target Plant Concept, plants are grown in the nursery with the view of their fitness to thrive on the outplanting site and their ability to fulfill the project objectives.

The second component of the Target Plant Concept is the process of defining the target plant materials. The nursery manager and client use the characteristics of the outplanting site to systematically answer eight sequential, but interrelated questions (figure 3.1) to ultimately define the target plant material.

1. What Are the Outplanting Objectives?

Native and traditional plants are grown for a variety of reasons; these project objectives critically influence target plant characteristics (figure 3.5).

In the tropics, project objectives may include reforesting land that has been deforested; enriching sustainable agriculture with windbreaks or erosion control using native species; providing shade in pastures; producing timber or wood for crafts; rekindling traditional agroforestry practices; ensuring local supplies of cultural or medicinal plants; restoring degraded land; controlling invasive species; creating habitat for pollinators, birds, or wildlife; planting native trees in urban areas; protecting and producing traditional foods; conserving soil and water quality; educating young people; and developing small businesses. Some projects hold a combination of objectives.

Figure 3.5—Native and traditional plants are grown for a variety of project objectives, which critically influence target plant characteristics. Objectives may be production of teak for commercial timber in Samoa (A); regeneration of heritage species, such as breadfruit trees, for food security (B); perpetuation of native and traditional species to sustain traditional lifeways and craftspeople (C); and reforestation of sites overcome by invasive species, such as this swordgrass area on Guam (D). Photos by Thomas D. Landis.

See the following examples of how target plants are linked to project objectives:

- Commercial timber production is a common objective for planting trees. For this objective of producing saw logs, the target plant would be a commercially valuable tree species that has been genetically selected for fast growth, good form, or desirable wood quality.
- The target plant for a watershed restoration project to stop erosion, stabilize the stream bank, and ultimately restore a functional plant community could be riparian trees and shrubs with extensive root systems and thick stems to withstand flowing water.
- Projects restoring threatened or endangered native plant species require target plants that perpetuate the genetic diversity and unique adaptations of these imperiled local populations or may require target plants that can restore or create critical habitat for these ecologically important species.
- Projects to restore or enhance food security and food sovereignty might require target plants that are native foods and cultivars of traditional or heritage food plants and varieties. Target plants may also include species and genotypes that yield the most or best-quality fruits, nuts, or other food.
- Project objectives for a burned, eroding former sugarcane field might be to stop soil erosion, replace exotic weed species with native or other desirable plants, restore nutrient cycling, and build up organic matter for future productivity. Target plants for such a project might include a direct seeding of native grasses and forbs or possibly a noninvasive annual plant to first stabilize the soil, followed by an outplanting of native nitrogen-fixing trees and other species to out-compete the weeds and build fertility on the site. These actions can improve site conditions over time. Later, more diverse species can be planted.
- Renewing native and traditional species for crafts or other cultural uses is an objective for many projects. Target plants may include local cultural plant species to help protect wild plants from the stresses of over-collection and to make their collection and use more accessible to elders and young people.
- Some projects have the objective to reduce the effects of weeds or invasive species. The presence of invasive exotic plants is often a result of disturbances that create ideal conditions for these plants to thrive. Therefore, simply removing undesired species does not solve the problem. Instead, undesirable plants must be replaced with desired ones. For example, most invasive grasses thrive in full sun, so the target plant to shade out the grass would need to be large enough to overtop the grass immediately after outplanting, and quickly form dense shade.

Sometimes project objectives are straightforward and target plants are easily defined. For complex, large, or specialized projects, such as Forest Stewardship, conservation, or habitat improvement, the assistance of a professional may be needed. This expertise helps define objectives and target plant material requirements for every species to be planted. Many restoration projects follow an approach that includes finding reference sites, considering succession, and creating measurable goals.

Selecting Reference Sites

"Reference sites" are natural or recovered areas that serve as models for desirable recovery of native plant communities (figure 3.6A). The comparison of the soils, climate, vegetation, and other characteristics of reference sites to the project site provides guidance about what species may be established and is essential for setting attainable, site-appropriate goals for restoration (Steinfeld and others 2007) (figure 3.6B). Often several reference sites of different ages and recovery stages are used for one project. Reference sites also show succession, which is how plant communities may change over time.

Planning for Succession

Land managers need to understand not only how a healthy 200-year-old forest looks, but also how a healthy recovering tropical forest looks 1, 3, or 5 years into its development. Understanding this recovery process is necessary because if native species can colonize and become established on a disturbance, the processes of succession (ecosystem development over time), including soil genesis and nutrient cycling, are initiated (figure 3.7). Effective revegetation of disturbed sites aims to initiate or accelerate processes of natural succession following disturbances. Native plants may be established on disturbed sites through seeding or planting (figure 3.8). Sometimes passive revegetation (natural colonization) of some species is possible where native seed banks are available and limiting factors are mitigated. If passive restoration is possible, nurseries may be involved in growing enrichment or later successional species that will not regenerate on the site naturally.

Translating Objectives into Measurable Goals

Some projects formally translate their objectives into measurable goals within specified time frames. These goals

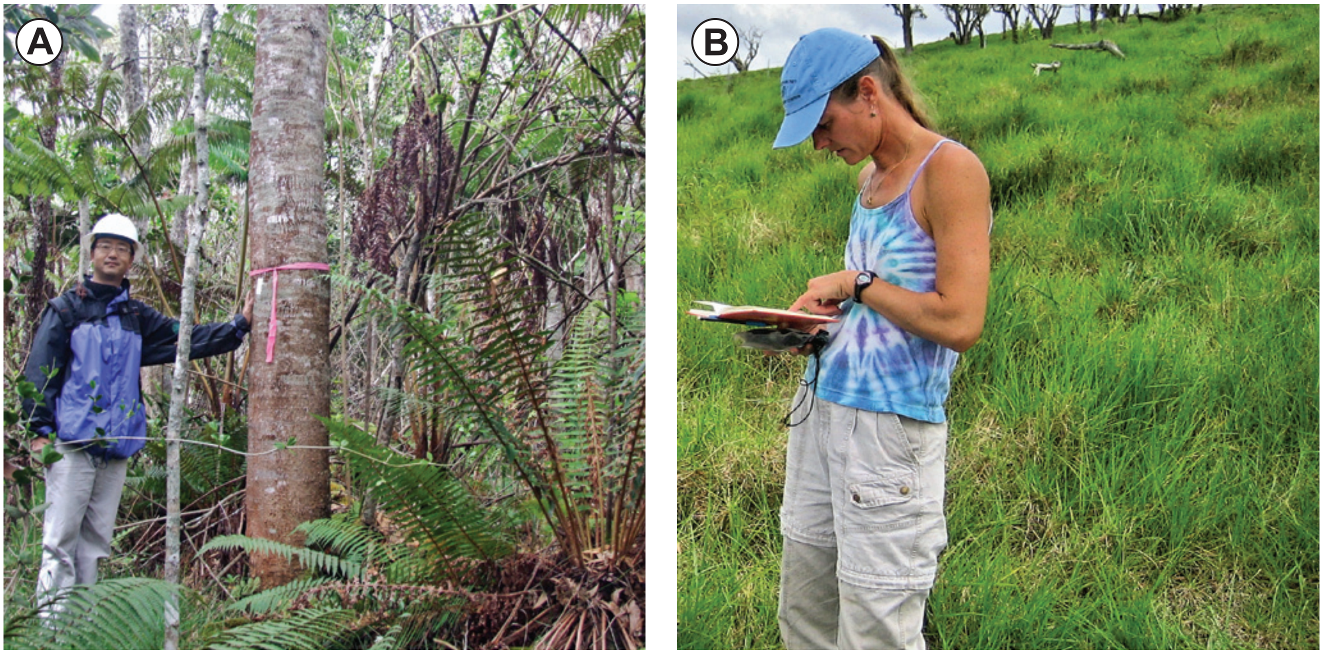

Figure 3.6—*Reference sites provide guidance about setting attainable, site-appropriate goals for restoring the outplanting site, including which species to plant. Information about conditions on reference sites is compared with the conditions on the outplanting site. Measuring trees on a regenerating, 30-year-old stand of native forest after cattle were removed from a pasture (A); surveying a pasture where forest recovery is desired (B). Photo A by J.B. Friday, and photo B by Douglass F. Jacobs.*

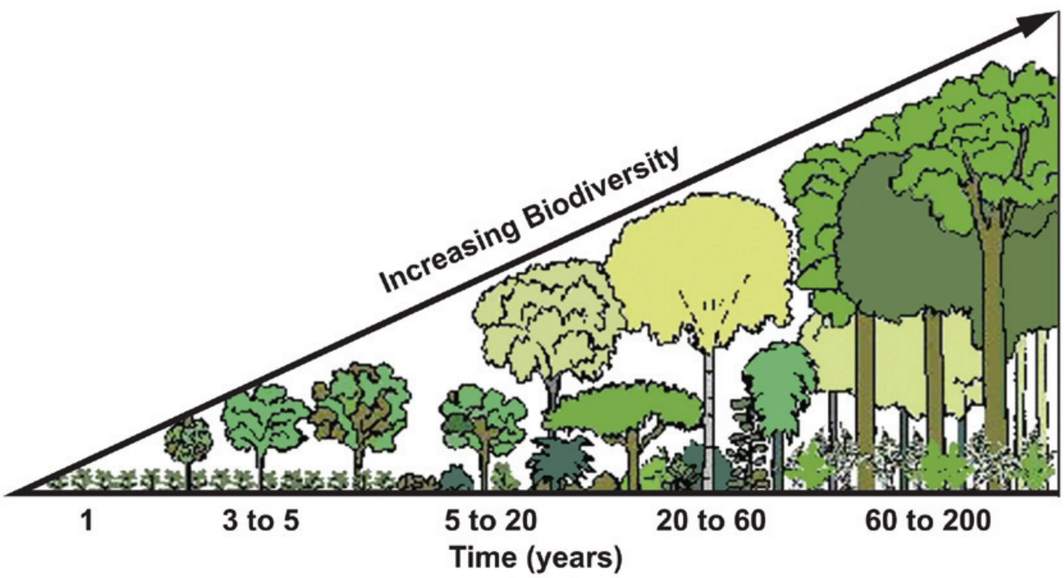

Figure 3.7—*Effective revegetation of disturbed sites aims to initiate or accelerate processes of natural succession following disturbances. Reference sites of different ages (5 years recovered, 20 years recovered, and so on) help to set reasonable timelines and appropriate species compositions for project development. Illustration adapted from Cerro Nara Rainforest Conservation (2010) by Jim Marin.*

are sometimes called success criteria or desired future conditions. For example, a reforestation project might set a goal of 400 living trees per acre 2 years after outplanting whereas a native plant project may have a goal of 75-percent vegetative ground cover of which 90 percent will be composed of perennial native species 1 year after outplanting. Production of food, craft materials, or timber might be stated in yields. Habitat restoration will define desired fauna moving into the planting area and will provide information about the plants themselves. Many restoration projects take place in stages. Short-term objectives might be to stabilize the soil and reinitiate natural succession, whereas longer term objectives include greater diversity and complexity. Monitoring is then planned to measure if these goals were achieved. See Chapter 17, Outplanting, for more information.

2. What Are the Conditions of the Outplanting Site?

Site evaluation is necessary for clients to determine their target plant requirements and achieve their goals. The information-gathering step may be informal, based on observation and spending time on the site. More complex projects often involve different tests and a systematic approach to determine site conditions. The most elaborate site assessments are usually carried out to meet regulatory requirements, such as a project requiring an environmental impact statement before it can proceed. For restoration of disturbed sites, the reference sites described previously are also surveyed to compare their conditions with those of the outplanting sites. At a minimum, basic land features need to be mapped and the site evaluated for basic information about soils, vegetation, climate, and site history.

Maps

Finding or creating a basic site map is an important step for projects of any scale. Topographic maps and aerial photos are especially useful and usually easy to find. Topographic maps indicate elevations, contour lines, waterways and water features, slopes, aspects, and human-made features including roads and settlements. Aerial photos can reveal features such as vegetation, access, structures, and surroundings and offer a snapshot of the conditions at one point in time. Special maps can be obtained as needed for more detailed information such as hydrology, soils, or forest cover.

Soils

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) and other organizations have soil surveys available for many areas; these surveys provide basic information on soil type and slope. In addition, a soil test can provide information on pH and nutrients (the client can contact the extension service to find out how to supply a soil sample to a testing facility). The client's personal observations are also a valuable addition. From these tests and observations, challenges such as issues with drainage, compaction, erosion, incorrect pH, depth to water table, and so on can be identified. For projects on large areas, a soil scientist may be called in to survey the site and provide a report, usually in combination with the NRCS or other data.

Vegetation

Vegetation information is obtained by observing and recording the site's existing vegetation. At its simplest, clients walk their site and list the vegetation they see, getting some help from a plant-savvy friend for species they cannot identify. Often, publications are available to

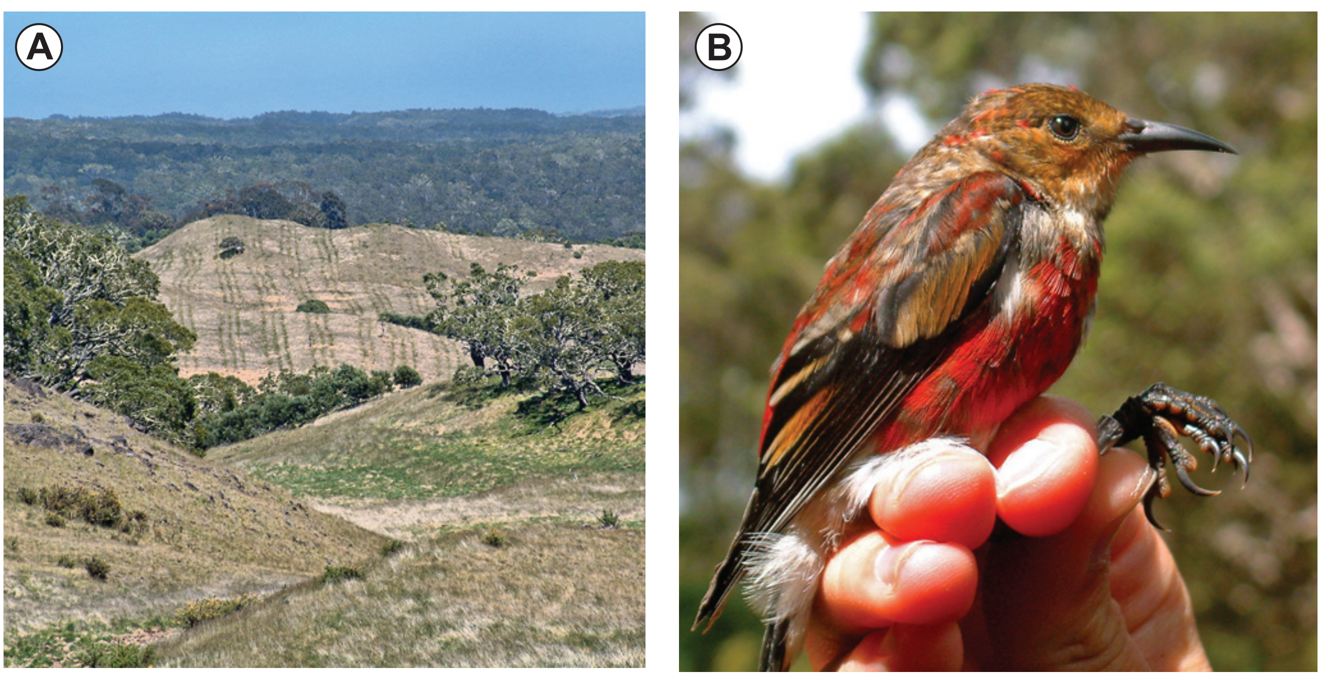

Figure 3.8*—At Hakalau Forest National Wildlife Refuge, koa (*Acacia koa*) seedlings are outplanted in three parallel lines marching up the hill from the lower forest to the upper pastures (A). The goal is to establish corridors so that the forest birds can increase their range uphill. Scientists at the refuge monitor the health and population of the native forest birds, such as this ʻApapane (*Himatione sanguinea*) (B). Photos by J.B. Friday.*

help identify plants and plant communities. More detail is reached when botanists survey the entire site and create a comprehensive list of species present, categorized as native, desired, or problematic, and sometimes further defined by successional phase.

When Global Positioning System (GPS) receivers are used for surveys, all the plant information collected is spatially explicit and mapping, analyzing, and sharing data becomes easier. Rapid Ecological Assessments are increasingly common and include vegetation mapping at various spatial scales. The advantage to this tool is that the data has a spatial component and the vegetation data is easily combined with soil and topography in a Geographic Information System (GIS).

Observing the vegetation also verifies and reveals additional characteristics of the site: dry areas, bogs, and areas subject to strong prevailing winds. Understanding the current vegetation is essential for site-appropriate actions later, including protecting and perpetuating native species already on the site.

Climate

Climate information can be obtained from national (for example, the National Oceanic and Atmospheric Administration) or regional weather service and charted back in some places for decades. At a minimum, clients need to understand the average rainfall and temperatures on their site and the fluctuations and patterns of these conditions throughout the year. For example, trends of when the rainy season normally starts and ends and the intensity of rain events are as important, if not more important, as only knowing the average annual rainfall.

Climate data is too broad to use on its own without also observing the microclimates on the site. Two sites situated only a few miles apart can experience dramatically different wind effects, rainfall, and temperatures (Mollison and Slay 1991). Onsite observation can help the client determine key climate information including aspect, winds, and moisture.

Aspect is whether a slope faces the sun (facing south above the equator or north below the equator) or away from the sun. Sun-facing slopes are warmer and drier; slopes facing away from the sun are cooler and wetter. Aspect is a major determinant of vegetation types on a site.

In most tropical areas, especially islands, storm winds and hurricanes may come from any direction, but prevailing winds are consistent and can be anticipated (Mollison and Slay 1991). Observing vegetation, especially trees bent or flagging in one direction, also indicates the direction of prevailing winds.

***Figure 3.9**—Native tree growers and their partners consult aerial photographs and discuss elevation, exposure, and other site conditions in preparation for a forest restoration project in St. Croix, U.S. Virgin Islands. Photo by Brian F. Daley.*

Water and the way it moves through a site are important factors for microclimate. Salt spray, fog, and mist can influence site conditions. The site's proximity to the ocean will determine the extent of the moderating effects of the ocean. Water features such as ponds, lakes, springs, and streams also create microclimates that affect vegetation.

Site History

Site history can be as simple as asking the elder neighbors about the past uses and conditions of the site, or as elaborate as a full archeological survey (required for some projects). An intermediate option is going to the local library or to the Internet to find aerial and other photos of the site dating back over time (figure 3.9). Cadastral offices provide publically available information on zoning changes, construction, and ownership changes of parcels. Information from the soils, vegetation, and climate surveys can be used to understand site history including floods, landslides, fires, severe storms, and other events that took place in the past and may take place again.

3. What Factors on the Project Site Could Limit Success?

The information gathered answering question 2 is used to identify the environmental factors that are most limiting to plant survival and growth on the site and to specify which plant species and stocktype would be most appropriate (figure 3.10 and table 3.1). On most outplanting sites, newly planted plants must quickly establish root contact with the surrounding soil to obtain enough water to survive and grow. Water is often the most limiting factor, especially on sites with a pronounced dry season or low annual rainfall. Where populations of grazing and browsing animals are high, animals may be the

Table 3.1*—Comparison of different plant establishment methods. Adapted from Landis and others (1992).*

Characteristics	Transplanting wildlings	Outplanting nonrooted cuttings	Direct seeding	Outplanting nursery stock
Efficient use of seeds and cuttings	N/A*	No	No	Yes
Cost of establishment	High	Moderate	Low	Moderate
Ability to establish difficult species	Yes	No	No	Yes
Option of using specific genotypes	No	No	Yes	Yes
Precise scheduling of plant establishment	Yes	Yes	No	Yes
Control of stand composition and density	Yes	Yes	No	Yes
Matching stocktypes to site conditions	No	No	No	Yes
Depletion of adjacent plant stands	Yes	Yes	No	No

*N/A: Not applicable.

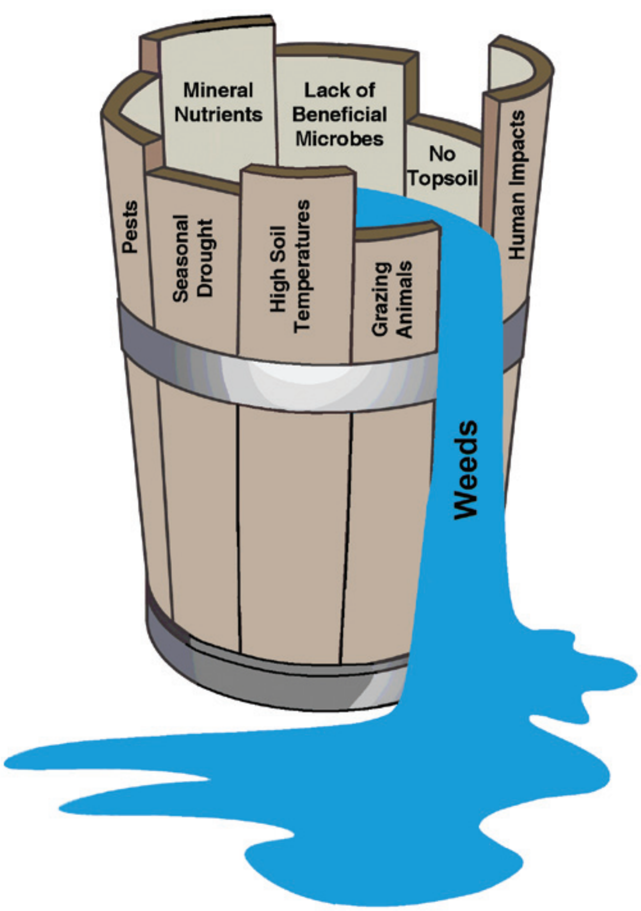

Figure 3.10*—Limiting factors to a given project site can be displayed as unequal boards of a barrel. Water can only be held to the level of the most limiting factor. Illustration by Jim Marin.*

most limiting factor because they will eat any plants you try to establish. If wildfire is a recurring disturbance on the site, then soil conditions are often severely altered and very specific measures, such as fire breaks are essential in the early years of the restoration project. Severe soil disturbances can also eliminate all soil microorganisms including mycorrhizal fungi. Therefore, plants destined for severely altered sites need to be inoculated with the appropriate symbionts before outplanting. (See Chapter 13, Beneficial Microorganisms, for a complete discussion on this topic.) Riparian restoration projects may require bioengineering structures to stabilize streambanks and retard soil erosion before the site can be planted (Hoag and Landis 2001). In desert areas, low soil moisture, hot temperatures, and high winds with sand blast may be listed as limiting factors. High winds, salt spray, weeds, soil fertility, seasonal flooding, insect pests, and land use challenges, such as people driving over restoration areas, are further examples of limiting factors.

Awareness of native plant needs and ecology (based on reference sites) is important to determine if the factors are truly limiting based on project objectives. For example, a site may not receive much rainfall, but if the goal is dryland ecosystem restoration and the dryland native species are adapted to that amount of rainfall, these plants will be able to thrive on the site.

4. How Will Limiting Factors Be Mitigated?

Mitigating measures are the steps the client will take to overcome any limiting factors on the site and achieve project

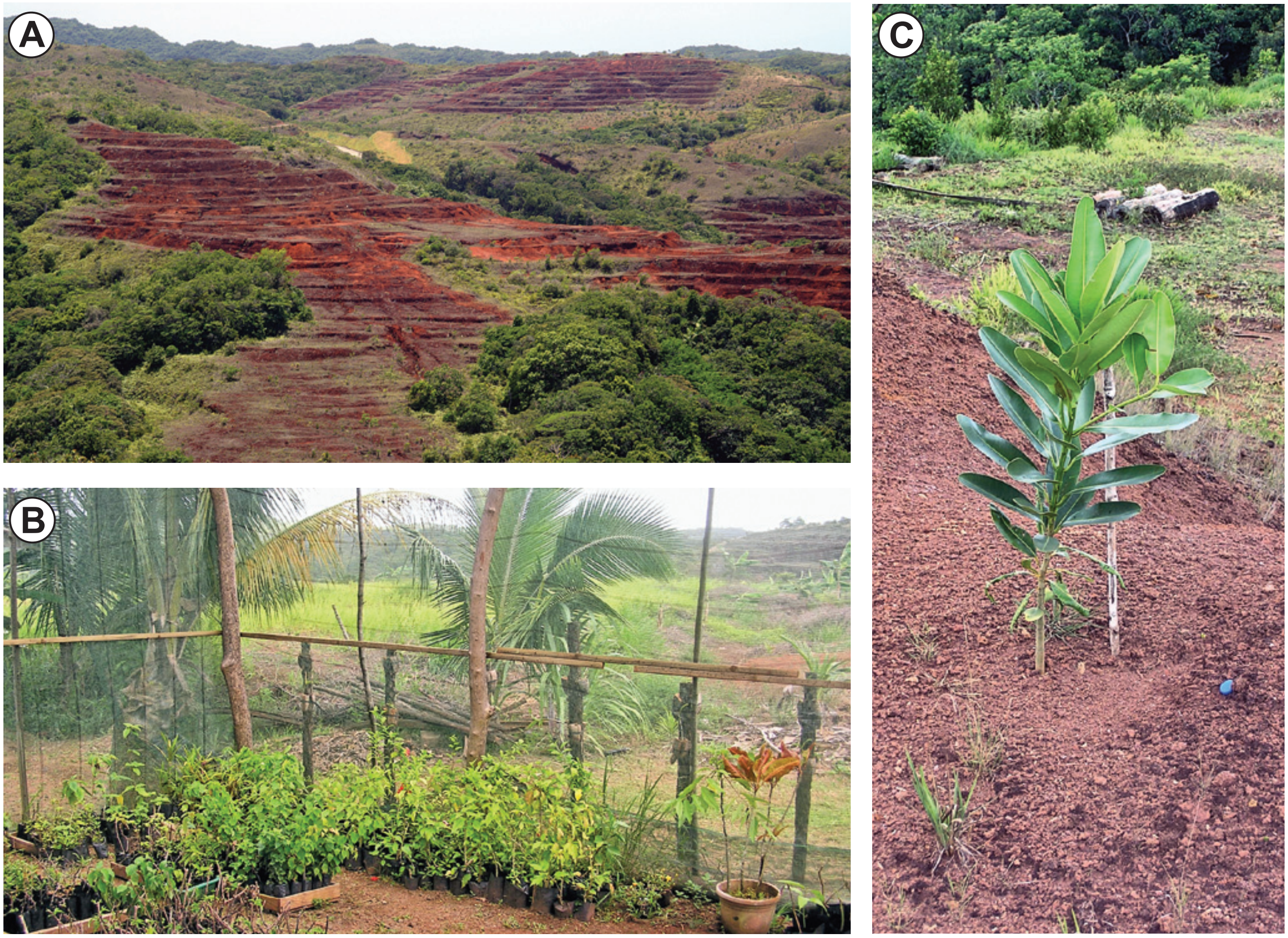

Figure 3.11—*Target plants are cultivated with the limiting factors of the site in mind. "Badlands" on the main island of Palau are bauxite mining areas developed before World War II that are still not revegetating (A). Nursery site for native seedlings for restoration of the mined site (B). A native species,* Calophyllum inophyllum*, outplanted on the badlands (C). Photos by George Hernández.*

objectives. Some mitigating measures can be defined by the client and included in his or her target plant requirements (figure 3.11); others must be carried out by the client on his or her site to establish plants successfully.

Nursery efforts to produce target plants will sometimes be the key to overcoming certain limiting factors on the site. For example, an absence of beneficial microorganisms on the site can be mitigated by inoculating plants with beneficial microorganisms in the nursery, as described in Chapter 13, Beneficial Microorganisms. Sometimes mitigating measures will be a combination of nursery efforts to produce target plant materials and client efforts on the site (figure 3.12). For example, sites with strong prevailing winds may call for target seedlings with sturdy, thick stems to withstand the winds; at the same time, the client may install wind barriers around the trees to help them get established, or windbreaks may be planted to protect the area in advance of other plantings.

Figure 3.12—*Overcoming limiting factors to restore disturbed sites involves a combination of nursery and land manager efforts. On a site with tall grass, the land manager would take steps to control the grass competition, and the nursery may also grow trees tall enough to overtop the grass quickly. Photo by Douglass F. Jacobs.*

For sites with browsing or grazing animals, species selection for less palatable species may be important, but the land manager must find ways to exclude these animals from newly planted areas or at least provide shelter for the plants as they establish (figure 3.13). Individual plants can be protected with netting or fencing or the entire project area may be fenced. In some areas, the presence of wild pigs or other animals may make restoration impossible, in which case, whole restoration areas may need to be fenced and managed to exclude problematic animals.

Limiting factors that cannot be mitigated through reasonable target plants and land manager efforts in the field require the client to revise project objectives to be appropriate and achievable on their project site.

Figure 3.13*—Goats eat anything—very few target plants could be cultivated to co-exist with goats. If goat browsing is a limiting factor, the land manager will need to exclude goats with fencing. Photo by Kim M. Wilkinson.*

5. What Species and Genetic Sources Will Meet Project Objectives?

Land managers decide what species they will plant based on project objectives, reference sites, project site conditions, and limiting factors as described previously (figure 3.14). The reference sites provide a natural model for determining appropriate species and plant community composition (what percent of which species, spaced how far apart) for the recovering site (figure 3.15).

In some cases, mitigation of limiting factors alone is sufficient to allow for natural regeneration (passive restoration) of certain native and desirable plant species on the site. For example, on some upland sites in Hawaiʻi, simply removing grazing and browsing animals and scarifying the soil allows long-dormant koa seeds in the seed bank to sprout (figure 3.16). In these cases, the nursery work may focus on those species that do not regenerate naturally. On many disturbed sites, however, no amount of mitigation will lead to adequate natural regeneration of native or desired species, and in these cases, the nursery will be involved in propagating these species for reintroduction by planting.

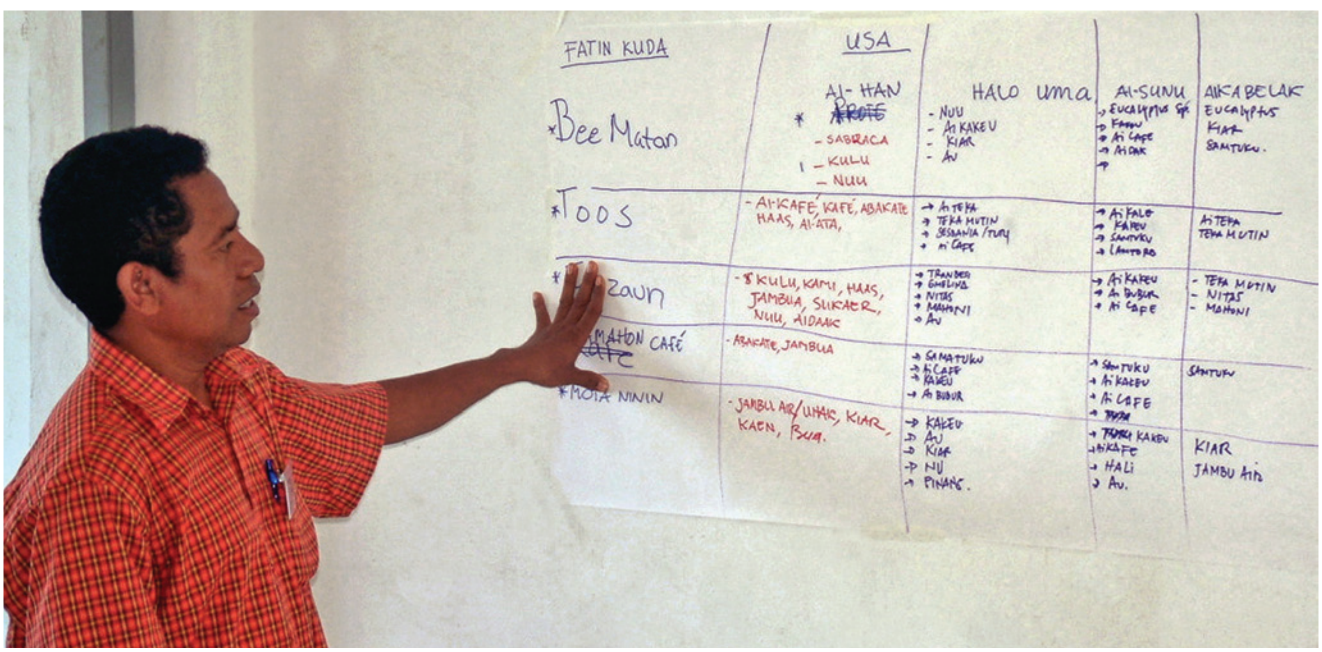

Figure 3.14.*—A forester in East Timor develops a tree selection chart for different planting sites (along the left) and different uses (across the top). Planting sites include near springs and on farm fields. Uses include food, fallow improvement, firewood, and timber. Photo by J.B. Friday.*

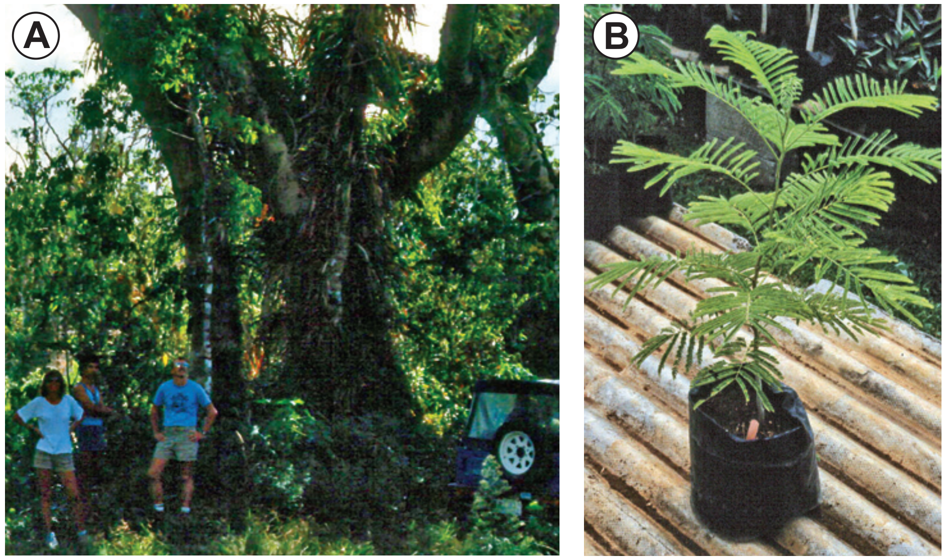

Figure 3.15—Reference sites and succession processes guide which species to plant. One of the few endangered Serianthes nelsonii *trees surviving on Rota (A). Because natural regeneration is not enough to sustain populations, nurseries on Rota produce* Serianthes nelsonii *seedlings (B). Photos by Thomas D. Landis.*

Of course, most nurseries have the occasional call from a person who asks, "What should I plant?" It is not surprising that some potential clients expect the nursery to tell them what to plant. Using the Target Plant Concept, the client and the nursery work together to determine what plant species are appropriate to plant for a given site.

Genetic Sources

In addition to proper species selection, three factors concerning genetics need to be considered when collecting plant materials: local adaptation, genetic diversity, and sexual diversity. See Chapter 8, Collecting, Processing, and Storing Seeds, for additional information.

Local Adaptation

Plants are genetically adapted to local environmental conditions and, for that reason, plant materials should always be collected within the same area where the plants will be outplanted. "Seed zone," "seed source," and "seed lot" are terms used to identify seed collections. A seed zone is a geographic area that has relatively similar climate and soil type (figure 3.17). For some native species, seed zones or transfer guidelines have been defined by geneticists to help land managers choose appropriate seed sources. For most tropical native species, such work has yet to be completed, so growers are advised to use sources from the same geographic area, environmental conditions, and elevation in which the nursery stock is to be outplanted.

Figure 3.16—In some cases, some species may be able to regenerate naturally if limiting factors are removed. This photo shows natural regeneration of Acacia koa *on an upland site after grazing cattle and horses were excluded. Photo by Douglass F. Jacobs.*

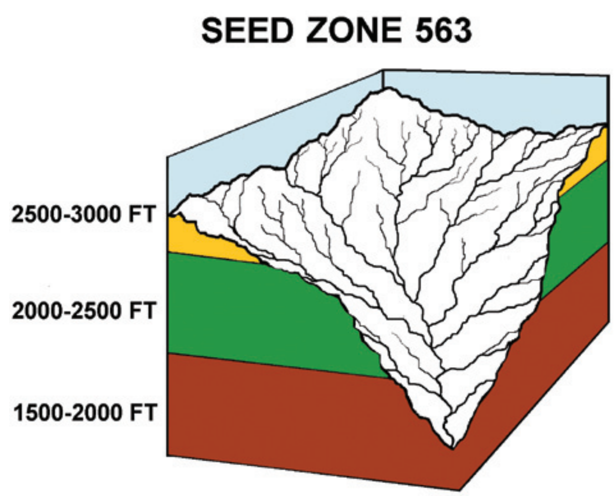

Figure 3.17—Seed zones have been developed for some species to provide guidelines for collecting seed from the same geographic area and elevation zone. Where no seed zones have been defined, do your best to collect plant materials from the same geographic area, environmental conditions, and elevation in which the nursery stock is to be outplanted. Adapted from St. Clair and Johnson (2004).

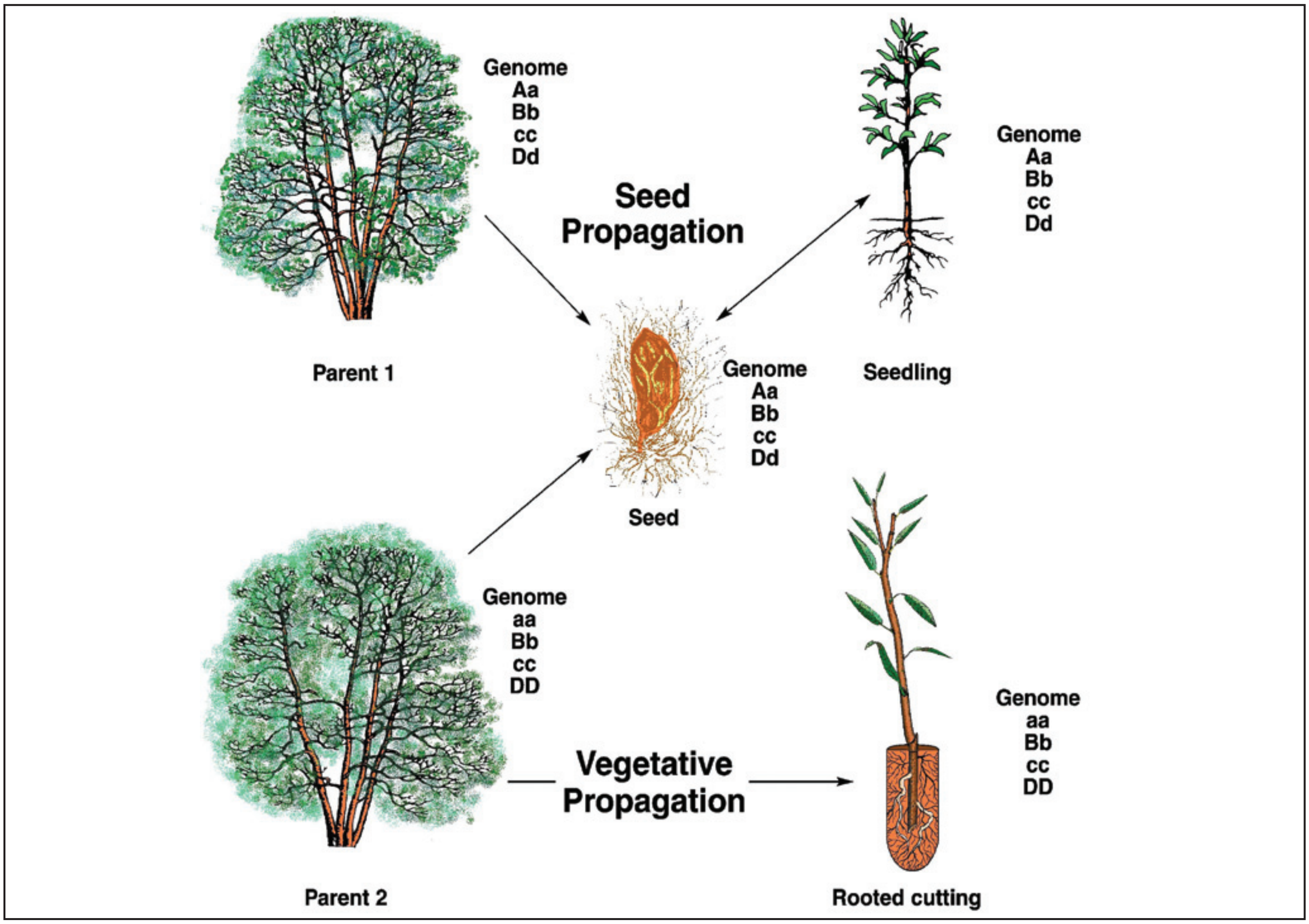

Figure 3.18*—When collecting seed or cuttings from plants, genetic and sexual diversity must be considered. Adapted from Landis and others (2003).*

Local adaptation can affect outplanting survival and growth in many ways, including growth rate and environmental tolerances. For example, in temperate areas, commercial conifers grown from seeds or cuttings collected from higher latitudes or elevations will grow slower but tend to be more cold tolerant than those collected from lower elevations or more southerly latitudes (St. Clair and Johnson 2003). Many tropical islands have a pronounced "wet side" and "dry side." Conventional wisdom and research (Ares and others 2000) indicates to refrain from moving plant materials from the wet side of an island to the dry side, or vice-versa. In addition to rainfall tolerances, local adaptation issues may be important for other site conditions such as soil types.

In some cases, local adaptation may be essential for long-term viability and habitat value of restoration plantings. For example, local pollinators are often adapted to the flower sizes and shapes of their locally adapted food plants (Kramer 2007). If a site is restored with the same species, but not the appropriate local adaptation of that species, local pollinators may not be able to pollinate them, leading to a project that cannot perpetuate itself.

Genetic and Sexual Diversity

Target plant materials should attempt to represent all the genetic and sexual diversity present on the reference sites (figure 3.18). To maximize genetic diversity, seeds or cuttings need to be collected from as many plants as possible. Guinan (1993) provides an excellent discussion of all factors involved in preserving biodiversity when collecting plant materials and suggests collecting from 50 to 100 donor plants.

Dioecious species are challenging because they have male and female plants. Therefore, all vegetatively propagated dioecious plants will be the same sex as their parent, which can be particularly important on sites where a male population is geographically separated from a female population. In such cases, plant material collectors may not realize they have collected only one sex, leading to a single sex being outplanted on a project site. The resulting lack of seed production would compromise project objectives and future natural regeneration. Therefore, when collecting cuttings from dioecious species, care must be taken to ensure that male and female

Figure 3.19—Pandanus tectorius*, an example of a dioecious plant of Polynesia. Photo by J.B. Friday.*

plants are equally represented. Dioecious species include cycads (Cycadaceae, Stangeriaceae, and Zamiaceae families), mulberries (*Morus* species), pandanus (*Pandanus tectorius*) (figure 3.19), kukui nut (*Aleurites moluccana*), and the rare Caribbean "yellow prickle" (*Zanthoxylum* species). Rooted cuttings or other vegetatively propagated stocktypes need to be labeled by sex so that males and females can be outplanted in a mixed pattern to promote seed production.

Additional Considerations About Source

To meet project objectives, other selection factors may be considered when defining the appropriate propagule sources. In special cases, seeds must be collected from parents that possess desired attributes. For example, if a native or traditional species is being grown for timber or craft use, seeds need to be collected from trees showing the desired form or wood characteristics. Plants grown for traditional medicinal purposes must meet the end user's exacting requirements for quality and potency of the source plants (figure 3.20). When applicable, these other source considerations are in addition to, not instead of, the three factors of local adaptedness, genetic diversity, and sexual diversity. For traditional species, the genetic situation needs to be considered on a case-by-case basis; sometimes perpetuating heritage varieties is the goal and sometimes improving the genetic diversity will be the goal.

Figure 3.20—Plant materials must be sourced from parents that possess the desired attributes, especially in the case of medicinal or food plants. Piper methysticum *(kava) is an important ceremonial and medicinal plant for many Pacific Island cultures, and different cultivars have different properties and concentrations of active compounds (A). The essential food plants* Colocasia esculenta *(taro) and* Musa *species (banana) have diverse heritage cultivars with a wide range of properties and tastes (B). Photos by Thomas D. Landis.*

6. What Types of Plant Materials (Stocktypes) Are Best Suited to the Project Site and Objectives?

Common plant materials include traditional nursery stocktypes, such as container seedlings, bareroot seedlings, and rooted cuttings, as well as wildings, rootstock, nonrooted cuttings, and seeds (table 3.2). Appropriate stocktypes for a project are determined by considering limiting factors, species, and genetics. The characteristics of a particular species will help determine if direct seeding, nursery propagation, or other methods are the more appropriate strategy (Steinfeld and others 2007). Many options can be considered; some options are summarized in table 3.1. Native plant nurseries can provide a wide variety of plant materials that will meet the needs of any reforestation or restoration project (table 3.2).

Table 3.2—Many different types of native plant materials can be provided by nurseries.

Plant materials	Examples	Advantages	Disadvantages
Seeds	Grasses, forbs	• Small and easy to outplant • Seeds of some native plants can be stored for long periods • Plants develop natural root structure • Maintain genetic diversity	• Some species do not produce seeds regularly • Many tropical seeds do not store well • Direct seeding more inefficient use of seeds than nursery plants
Bareroot plants	Coconut, mahogany, cedrela	• Less expensive to produce in nursery than container plants • Easier to transport • Roots have not been restricted by containers	• Take longer to produce • Roots dry out easily • Often lower survival and slower growth especially on drier sites
Container plants	All species	• Well-established root systems means less transplant shock • Available in a variety of sizes • Can be planted all year long • Large stocktypes provide "instant" plants on site	• More expensive to propagate • More difficult to transport, especially larger stocktypes
Root stock	Yams, kava, breadfruit, bananas	• Easy to store and transport • Excellent survival after outplanting	• Only works with certain species
Nonrooted cuttings	Erithrina, Gliricidia, gumbo-limbo, Guazuma ulmifolia	• Ideal for live stakes • Can be efficiently and economically produced in nursery stooling beds	• Only works with species that root easily • Best for mesic environments
Layer cuttings	Citrus, breadfruit	• Do not have to rely on seed crops • Ideal for maintaining same genotype	• Requires healthy mother plant • Only works with species that root easily
Rooted cuttings	Many species	• Do not have to rely on seed crops • Ideal for maintaining same genotype • Stooling blocks can be developed for large multiyear projects	• Must be handled carefully during transportation and outplanting

Seeds

Seeds are often easy to handle, store, and outplant, but the effectiveness of seeding directly on the project site varies with species, harshness of the site, project objectives, and project timeframe. Directly broadcasting seeds offers three principal advantages: (1) seeds can be inexpensive compared with other plant materials, (2) spreading seeds is relatively easy, and (3) seedlings from broadcast seeds develop a natural root system and occur in a more random (that is, "natural") pattern.

Many drawbacks exist as well. Even when the correct species and origin are located, seeds are (1) often difficult to obtain or are very expensive; (2) not produced in adequate numbers every year; (3) sometimes require specialized cleaning and processing; and (4) difficult to store. In addition, predation by birds and rodents, competition from weed species, and unpredictable weather often reduce establishment success (Bean and others 2004). Finally, with direct seeding, it is difficult to control species composition and plant spacing over the project area (Landis and others 1992).

Direct seeding is usually most successful for grasses, forbs, and some woody shrubs. Seeding with native grass species after wildfires is often used to stabilize soils and prevent erosion. Some trees may be established through direct seeding, particularly those with large seeds. In California, the direct seeding of acorns to establish native oaks has been quite successful (Landis and others 1992). Sowing seeds directly in the field may result in poor germination and survival. Therefore, direct seeding is recommended only for species in which efficient use of seeds is not necessary.

Bareroot Plants

Bareroot plants are started from seeds or cuttings, are grown in the ground or in raised beds, and are harvested without soil around their roots (figure 3.21). Because they require a considerable amount of high-quality soil and often take longer to reach shippable size, fewer species of native plants are grown for conservation and restoration as bareroot stock than are grown for commercially important objectives, such as timber production. Tropical soils are challenging to work with, so bareroot plants are usually produced in raised beds with a mix of growing media (for example, sand mixed with compost) on a drip irrigation line. One serious drawback is bareroot stock needs more postharvest care than container stock. Bareroot is suitable only for plants with root systems that

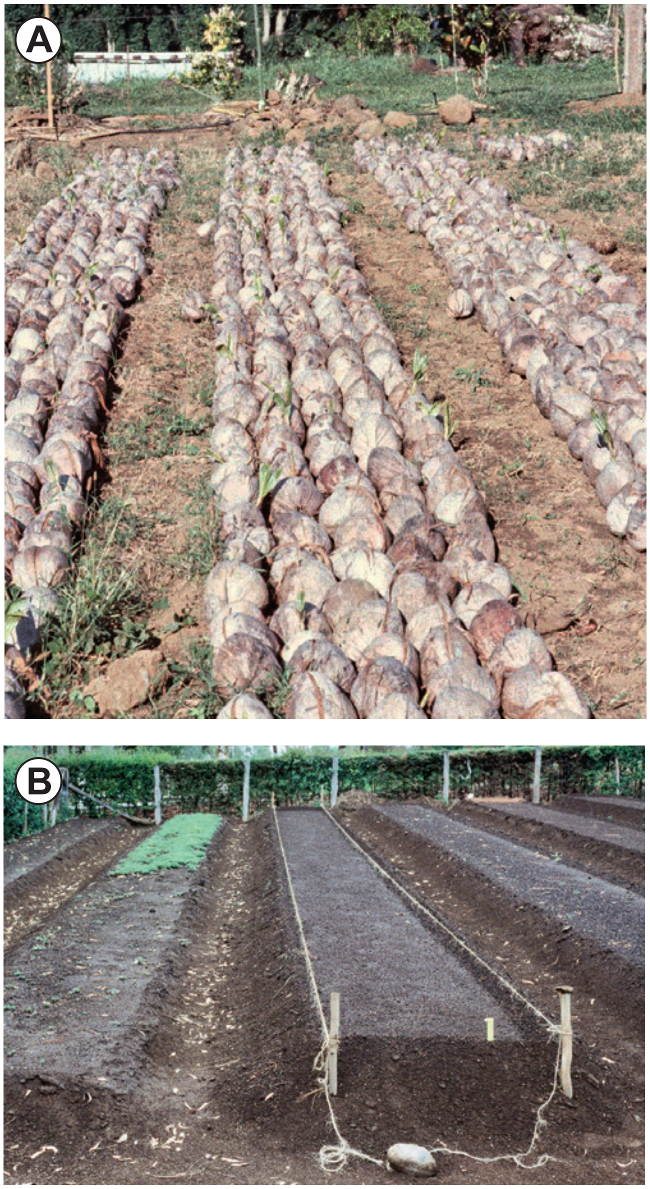

Figure 3.21—Bareroot coconut plants (A) are grown in fields and are harvested and shipped with no soil surrounding the roots. Tropical soils are challenging to work with, so bareroot plants are usually produced in raised beds (B). Photos by Thomas D. Landis.

can tolerate more disturbance and handling than species that need their root systems kept in contact with soil during harvest, shipping, and outplanting.

Container Plants

Container plants are the stocktype of choice for many tropical nurseries. Container propagation is best when small amounts of many different native plants are desired. Another advantage is that container stock is more tolerant and durable during handling, shipping, and outplanting (figure 3.22). Trees and shrubs are typically established

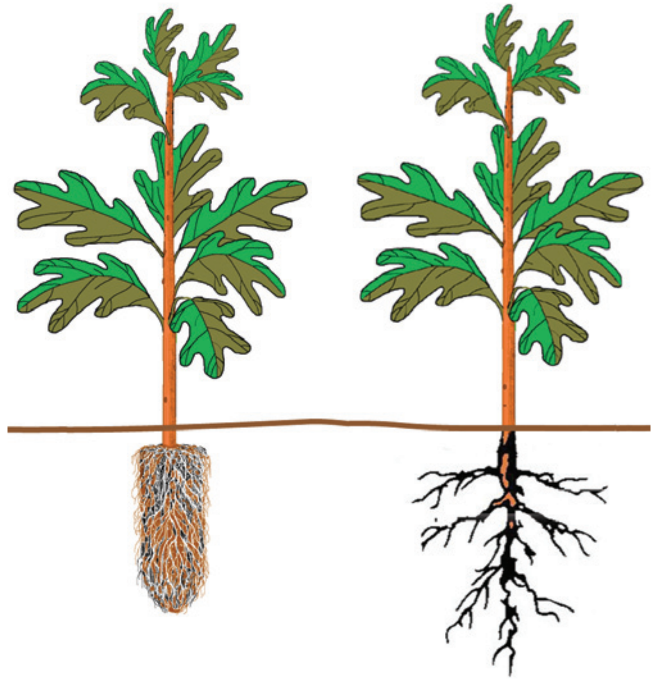

Figure 3.22—Container plants (left) and bareroot plants (right) have different morphological characteristics. Container plants come in many types and sizes but all form their roots into a plug resulting in less disturbance to the root system during harvest and outplant. Illustration from Dumroese and others (2008).

using container stock rather than by direct seeding for two reasons. First, obtaining seeds from most tree and shrub species is expensive and time consuming; in many years, seeds can be difficult to find. Second, shrub and tree seeds germinate and grow into seedlings at a slower rate than grass and forb species, giving them a disadvantage on sites where grasses and forbs are present. Outplanting shrubs and trees as plants gives them a competitive advantage over grasses and forbs because the plants have access to full sun and roots are often longer and better developed, allowing access to deeper soil moisture. In general, grass and forb species are seldom established from container plants because of the high cost. Exceptions are when grass or forb seeds are rare or hard to collect or propagate; if species are difficult to establish from seeds on disturbed sites; or when the project requires restoring threatened or sensitive species (Steinfeld and others 2007).

Container seedlings can range in size from tiny liners and plugs to large pots containing many gallons of growing medium. Because containers come in many sizes and shapes (figure 3.23), they can be matched to the project objectives and site conditions. When ordering container plants, age, stem diameter, height, root size, and depth are usually specified, in addition to species and seed source. See Chapter 7, Containers, for more information.

The distinguishing feature of container seedlings is that, because the roots are restricted, they bind growing media into a cohesive "plug" (figure 3.23) making outplanting easier, especially on harsh sites.

Wildings

Plants are typically grown in a nursery. For some projects, however, plants are salvaged from areas, such as development sites or roadsides, before planned disturbances. Salvaged plants (sometimes called wildings) can be an important component of protecting native plant diversity. Sometimes salvaged plants are simply relocated quickly from one area to another. At other times, plants may be transplanted into a nursery, cared for, and outplanted at a later time (Steinfeld and others 2007).

Nonrooted Cuttings

Long "pole" cuttings are a common type of nonrooted cutting used extensively in the tropics as live fence posts. Sometimes called "quick sticks," these nonrooted stakes of easy-to-root species, such as *Gliricidia sepium*, *Erythrina* species, or *Bursera simaruba*, are cut from the major branches or stems of trees. They are inserted into the ground with a minimum of 1 ft (30 cm) of the cutting in contact with the soil (ideally more). Pole cuttings are usually at least 4.0 ft (1.2 m) long and at least a 2-in (5-cm) diameter. Sometimes pole cuttings are used in riparian restoration projects (Hoag and Landis 2001). For this application, cuttings are often 6.0 ft (1.8 m) or more in length and up to 8- to 12-in (20- to 30-cm) in diameter so that they can be inserted deep enough such that the

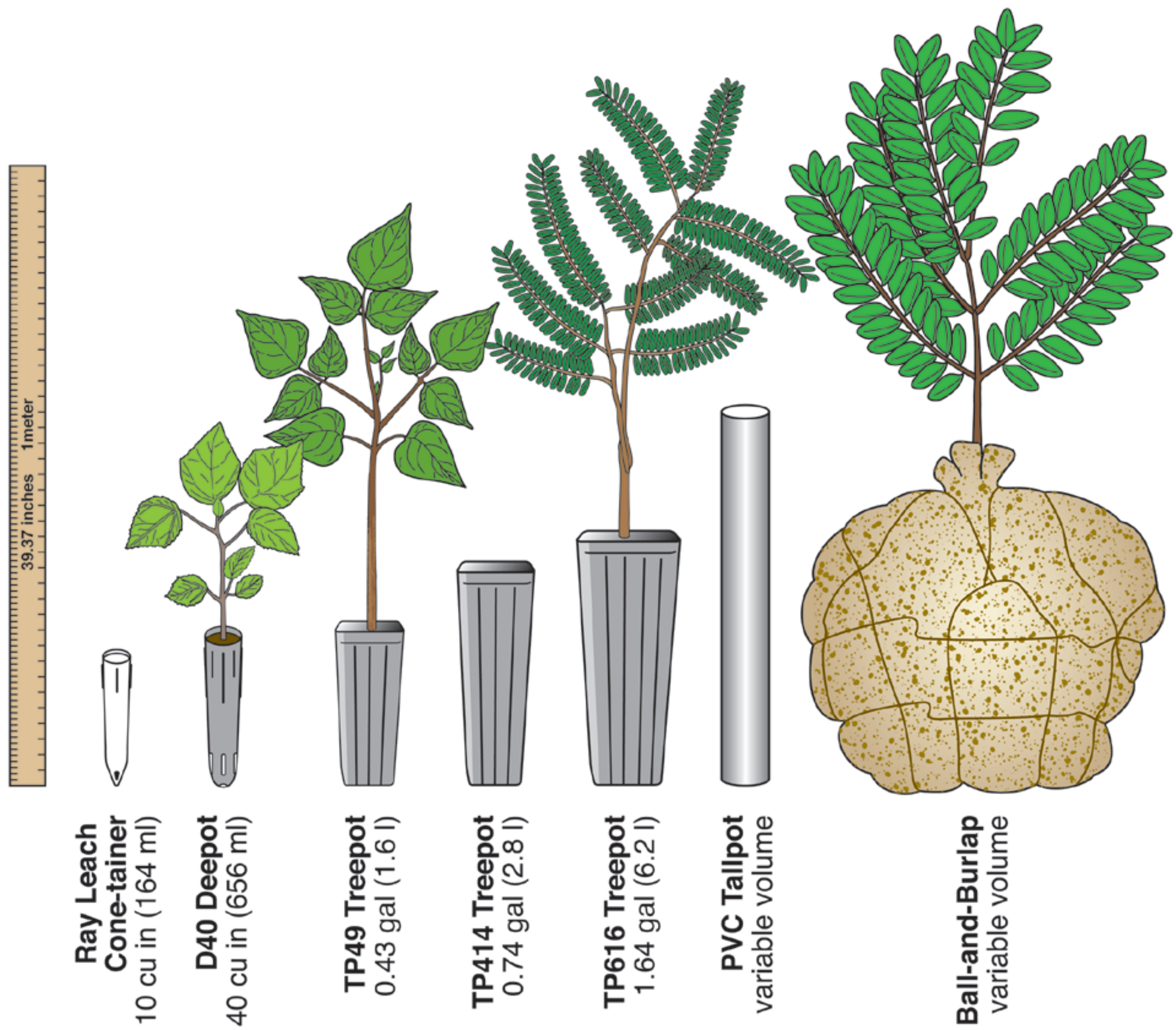

Figure 3.23*—Nursery stock can be grown in many sizes and shapes. Consider the advantages and drawbacks of different options when defining the target plant materials for a project. Illustration adapted from Steinfeld and others (2007) by Jim Marin.*

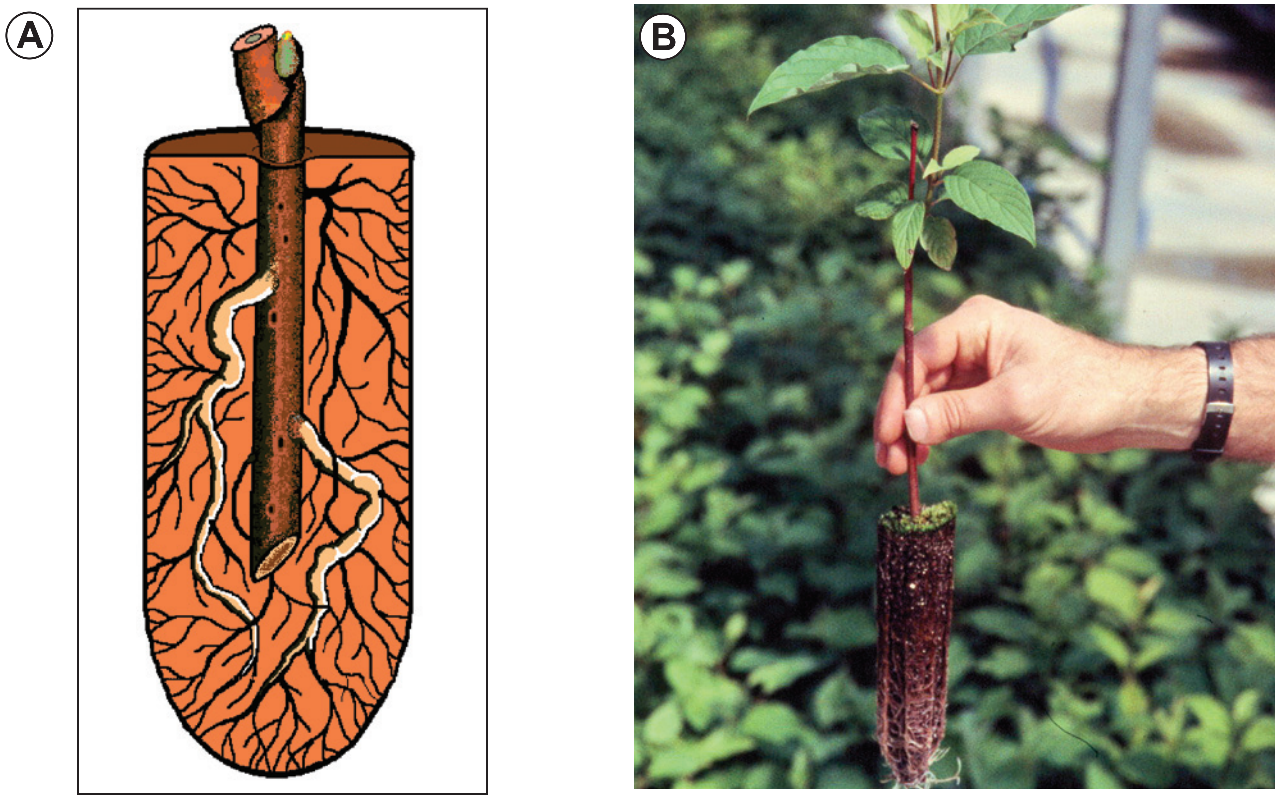

Figure 3.24—*Rooted cuttings use a shorter section of stem with a bud (A). Cuttings quickly grow into large plants under nursery culture (B). Illustration A from Dumroese and others (2008), and photo B by Thomas D. Landis.*

butt ends remain in contact with the water table. Pole cuttings are very effective in stabilizing stream or riverbanks because they resist erosion. When large numbers of poles are required, they can be grown in stooling beds in nurseries to avoid the negative effect of collecting from wild "donor" plants.

Rooted Cuttings

It is more effective to root cuttings of most woody species in a nursery before outplanting them on the project site. A 2- to 4-in (5- to 10-cm) stem section can be used (figure 3.24), but it needs to have a healthy bud near the top (Dumroese and others 2003). Some species, such as sweet potato (*Ipomoea batatas*), can be propagated from non-rooted vine cuttings, but may be easier to establish in the nursery if they are first allowed to root a little in water or a planting media before transplanting into containers. See Chapter 10, Vegetative Propagation, for more information about collecting and culturing rooted cuttings.

Rootstock

Rootstock refers to specialized roots, such as bulbs and corms, and to modified underground stems, such as rhizomes and tubers (figure 3.25). Rootstock can be

Figure 3.25—*Rootstock can be used to establish some grasses, sedges, forbs, and wetland plants that cannot be direct seeded or outplanted as seedlings. Photo by Thomas D. Landis.*

Figure 3.26*—The type of outplanting tool to be used is critical to defining the size and shape of the target plant. Photo by Thomas D. Landis.*

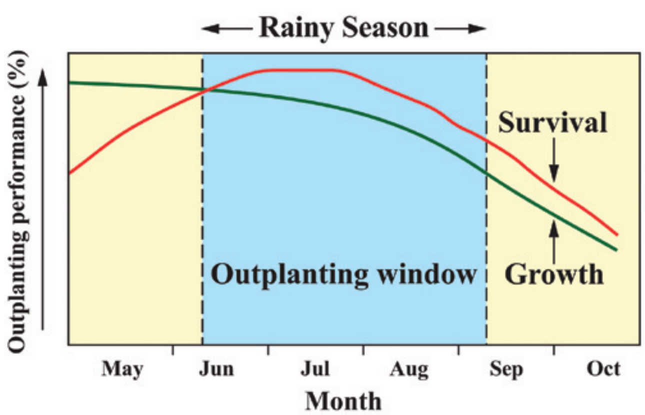

Figure 3.27*—The outplanting window is the period of time in which site conditions are the most favorable for plant survival and growth. The window will vary among geographical locations. For sites with a pronounced dry season, the outplanting window occurs at the onset of the rainy season. Illustration adapted by from South and Mexal (1984) by Jim Marin.*

used for the vegetative propagation of certain grasses, wetland plants, food plants, and even some trees. Examples of species propagated from rootstock include yams (*Diosorea* species), kava (*Piper methysticum*), and breadfruit (*Artocarpus* species). Bananas and plantains (*Musa* species) are often propagated from their corms or root structures.

7. What Are the Best Outplanting Tools and Techniques?

Each outplanting site has different climatic and soil conditions, so outplanting tools and techniques must be matched accordingly. Nursery managers must know in advance which planting tools will be used so they can develop proper plant material specifications, especially root length and volume or cutting length and diameter.

No single tool or technique will work well under all site conditions. For example, plants with narrow, long root systems may not be the appropriate root shape and size if deep, narrow holes are impossible to dig efficiently on the site because of rocky or muddy conditions. It is important to ensure that the planting holes are large and deep enough so that the seedlings can be planted properly.

Hand tools such as shovels (figure 3.26), pick mattocks, planting hoes ("hoedads"), and planting bars are very popular for outplanting native plants. Plants grown in deeper "tall pots" used in many restoration projects may require specialized outplanting equipment. Nursery managers must work closely with clients to make certain that their target plants can be properly outplanted in the soil conditions on the project site. A more complete discussion of outplanting tools and techniques is in Chapter 17, Outplanting.

8. What Is the Best Time for Outplanting?

Each site has an optimal time when chances for plant survival and growth are greatest—the "outplanting window." The outplanting window is usually defined by looking at the climate and historical information from Question 2 and the limiting factors described in Question 3. For example, in some tropical areas, soil moisture is the main limiting factor. In these cases, the outplanting window is at the onset of the rainy season when soil moisture is increasing and evapotranspirational losses are low (figure 3.27) Areas without a dry season may have other limiting factors, such as heavy rainfall and flooding, that define outplanting windows differently. The specific dates of outplanting windows will change with latitude and elevation.

In producing target plants for a project, the nursery must work backwards from the project's outplanting window to schedule propagation. This approach ensures the plants will be ready at the beginning of the outplanting window, as described in Chapter 4, Crop Planning: Propagation Protocols, Schedules, and Records.

Learning and Adapting: Field Testing the Target Plant

Starting small and expanding on successes is a basic principle of effective project management (Mollison and Slay 1991). If land managers are able to take a season or more to test out some plant materials and strategies before committing on a large scale, they can learn important lessons and ultimately increase their successes. At the start of any planting project, the land manager and the nursery manager need to agree on certain morphological and physiological specifications based on answers to the eight questions that define a target plant. This prototype target plant is grown in the nursery, and its suitability is then verified by outplanting trials that monitor survival and growth.

Monitoring survival and growth during the first few months after outplanting is critical because problems can show up soon after planting. Problems with seedling quality, poor planting, or exposure to drought conditions result in plants gradually losing vigor and perhaps dying. Therefore, plots must be monitored during the first month or two after outplanting and again at the end of the first year for initial survival. Subsequent checks after 3- and 5-year periods will give a good indication of plant growth rates. This performance information is then used to give valuable feedback to the nursery manager who can work with the client to refine the target plant specifications for the next crop (figure 3.1).

The strategy of starting small is not always possible. Some projects are urgent and require full planting as soon as possible. Clients with projects that must be planted all at once will not be able to benefit from the learning opportunities generated by the target plant feedback cycle. In such cases, the best available information and experience is used to define the target plants to immediately serve the client's needs. When the project is complete, however, the nursery and other people involved can still learn from the outcomes and apply the lessons to future projects of a similar nature.

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