The Container Tree Nursery Manual

Volume Seven

Chapter 1

The Target Plant Concept

Contents

7.1.1 Introduction

The basic ideas behind the **Target Plant Concept** can be traced back to the late 1970s and early 1980s when new insights into seedling physiology were radically changing nursery management. Forestry researchers began analyzing the effects of nursery cultural practices on outplanting performance and, as a consequence, foresters gave more thought to their reforestation prescriptions and began asking for new and different stocktypes (fig. 7.1.1). By 1990, the term *target plant* had become well established in nursery and reforestation jargon. In that year, the Target Seedling Symposium brought together foresters and nursery workers to discuss all aspects of the target plant, and the resultant proceedings are still a major source of information on the subject (Rose and others 1990).

Figure 7.1.1—*The "Target Plant Concept" developed as foresters and other plant users began to work more closely with nurseries to develop stocktypes for specific outplanting projects.*

One basic tenet of the Target Plant Concept is that plant quality is determined by outplanting performance (Landis 2002). Although they might be the same species, forest and conservation plants are very different from ornamental nursery stock. For example, Douglas-fir (*Psuedotsuga menziesii*) seedlings outplanted in relatively harsh forest environments will have different requirements from those outplanted in city parks or Christmas tree plantations. These differences are pivotal to the Target Plant Concept because plant quality depends on how the plants will be used—"fitness for purpose" (Sutton 1980). This means that plant quality cannot be merely described at the nursery; it must also be proven on the outplanting site. There is no such thing as an "all-purpose" plant because nice-looking plants at the nursery will not survive and grow well on all sites.

When defining a target plant for a particular project, economics and management objectives must be also considered. When different size classes of slash pine (*Pinus elliottii* var. *elliottii*) were outplanted and then measured after 4 years, seedlings with larger stem diameters had better survival and growth than the standard "shippable" nursery stock. An economic analysis proved that these larger plants were the best investment (South and Mitchell 1999).

7.1.2 Defining the Target Plant

A target plant is one that has been cultured to survive and grow on a specific outplanting site, and that can be defined in six sequential components (fig. 7.1.2).

7.1.2.1 Objectives of the outplanting project

The reasons why nursery stock is needed will have a critical influence on the characteristics of the target plant. In traditional reforestation, a commercially valuable tree species that has been genetically improved for fast growth, good form, or desirable wood quality may be outplanted with the ultimate objective of producing saw logs or pulp.

The target plant for a restoration project, however, might be radically different because the objectives are totally different. For example, a watershed protection project would require riparian trees and shrubs and wetland plants that will not be harvested for any commercial product. In this case, the objectives would include stopping erosion, stabilizing the streambank, and ultimately restoring a functional plant community. Fire restoration projects will have different objectives depending on the plant community type and the ultimate use of the land. Project objectives for a burned rangeland might be to stop soil erosion, replace exotic weed species with native plants, and establish browse plants for deer or elk. Target plants for such a project might include a direct seeding of native grasses and forbs, followed by an outplanting of woody shrub nursery stock. For a burned forest, however, the plant materials might be native grass seeds to stop erosion and then outplanting of tree seedlings to bring the land back to full productivity as soon as possible. Another project might be to restore plants that are in danger of going extinct in a particular habitat. For example, Short's goldenrod (*Solidago shortii*) is an endangered plant that can be found only in 14 populations in a small geographic area in Kentucky (Baskin and others 2000). Fortunately, this plant is relatively easy to propagate from seeds and grows well in greenhouses.

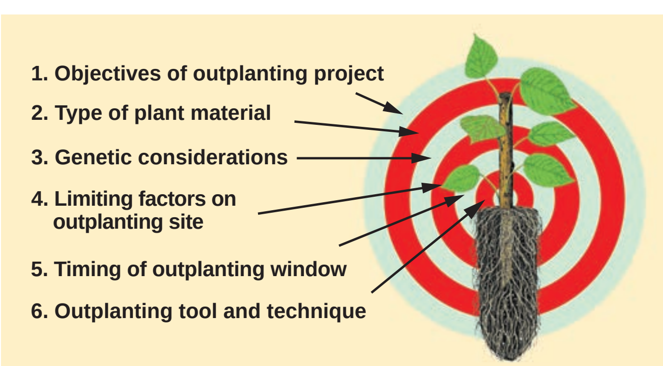

Figure 7.1.2—*The six components of the Target Plant Concept.*

Conservation planting projects can have still different objectives. Although native plants are emphasized whenever and wherever possible, exotic species may be required on extreme sites. In dry areas of the Intermountain West, where no native trees for upland sites are available, species such as Austrian pine (*Pinus nigra*) and Siberian elm (*Ulmus pumila*) are used to create windbreaks for home or livestock protection. Project objectives are a critical first consideration in the target plant concept.

7.1.2.2 Type of plant material

The second consideration in the Target Plant Concept is what types of plant material would be best (fig. 7.1.2). Plant materials refer to anything that can be used to propagate a species; these propagules can be seeds, bulbs or rhizomes, cuttings, or seedlings (Landis 2001). In container nurseries, plant material usually means the species and the stocktype.

Species. The species is determined by the project objectives that were discussed in the previous section. For example, Douglas-fir is one of the most important timber species in the Pacific Northwest and is therefore a major crop in local forest nurseries. Douglas-fir has been outplanted extensively for the past century, often in monocultures. In coastal areas of Oregon and Washington, these pure stands have recently become severely infected with Swiss needle cast caused by the fungus *Phaeocryptopus gaeumannii*. One silvicultural recommendation is to interplant with other conifers, especially western hemlock (*Tsuga heterophylla*), to reduce the effect of this disease (Filip and others 2000). In the Southeastern United States, the demand for longleaf pine (*Pinus palustris*) has increased tremendously in recent years and, for this species, container stock has proven to survive and grow better than bareroot stock (Barnett 2002).

Stocktype. Container nurseries currently produce a wide variety of stocktypes, including seedlings, transplants, and rooted cuttings. Although biological factors should be the primary consideration, the choice of container stocktype is primarily defined by price and preference. Experienced nursery customers consider the cost per surviving plant when deciding on stocktype and other target seedling factors.

Selling Price—Although the cost of containers and growing media are important, the price of container stock is basically a function of nursery production space. A unit area of greenhouse bench space costs a fixed amount, so the prices of the various container sizes increase as their cell densities decrease (table 7.1.1). Actual selling prices for each container size are set by market factors, especially demand and effects of competition.

Table 7.1.1—*Container seedling selling price is primarily a function of nursery production space*

Type of container		Cell volume		Number of cells per		Price per
		cm³	in³	m²	ft²	1,000 seedlings ($)*
Styroblock™ 1	207A	8	1.1	2,121	196	100
Styroblock™ 2A	211A	41	2.5	1,032	103	190
Styroblock™ 5.5	315B	90	5.5	756	71	276
Styroblock™ 10	415D	160	9.8	364	34	576
Styroblock™ 15	515A	250	15.3	284	26	755
Styroblock™ 20	615A	336	20.5	213	20	980

* Arbitrarily set price, U.S. dollars, 2007.

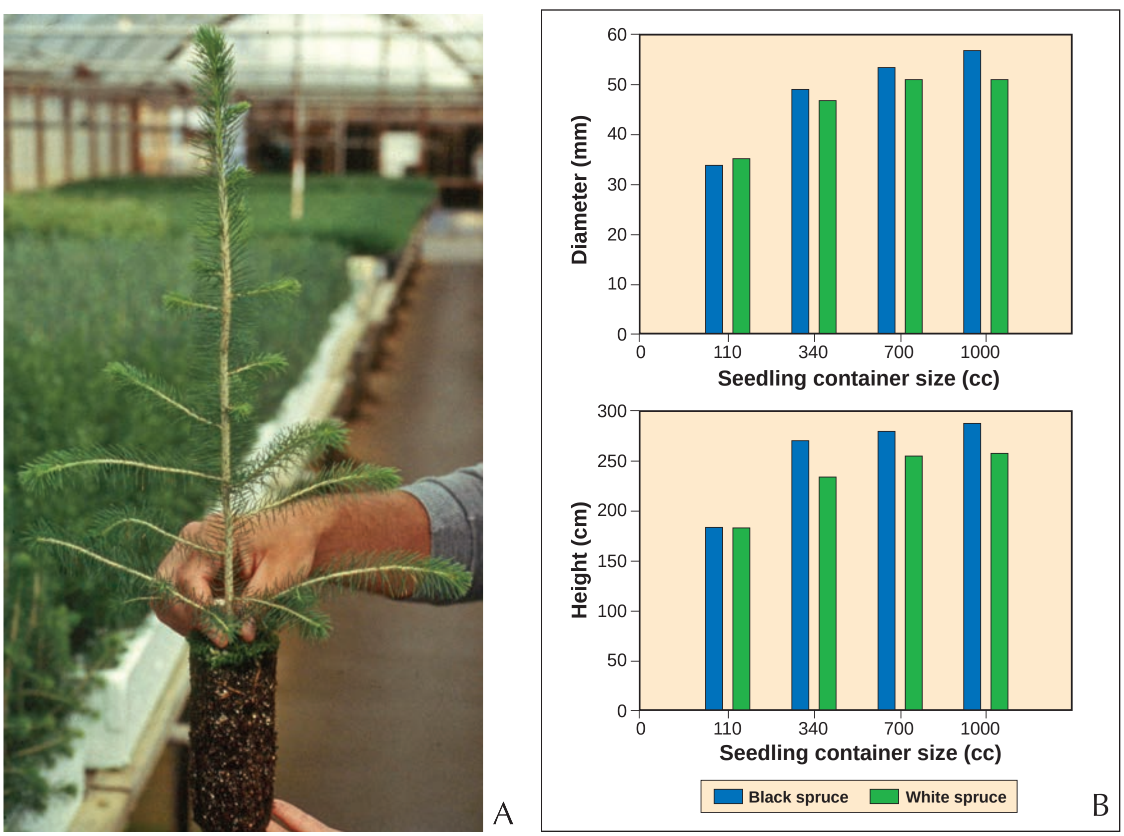

Figure 7.1.3—*Larger container plants are gaining in popularity (A), but outplanting trials are needed to determine which sizes grow best and are most economical. Eight years after outplanting, spruce seedlings in containers that were 340 cm³ (20 in³) in volume were the best choice on sites with heavy vegetative competition in Quebec (B).*

Customer Preference—The demand for container types has changed considerably over the past 25 years, and one trend is to larger volumes. For example, in the 1970s, one Oregon nursery typically produced container stock of 33 to 66 cm^3 (2 to 4 in^3), whereas, by year 2000 they were growing all their seedlings in 246 to 328 cm^3 (15 to 20 in^3) containers (fig. 7.1.3A). This preference for larger stocktypes has led to the practice of container transplanting, where seedlings are started in small "miniplugs" in greenhouses and then transplanted to larger containers grown in outdoor compounds.

One reason for larger container stocktypes to be in greater demand is because of increased vegetative competition on the outplanting site. Other factors being equal, plants grown in larger containers have larger caliper and a better shoot-to-root ratio, which gives them an advantage on sites with heavy competition. Environmental concerns in Quebec have led to a prohibition of herbicide use for site preparation. The standard stock size for black spruce (*Picea mariana*) and white spruce (*Picea glauca*) on these sites was 110 cm^3 (7 in^3), and, therefore, research trials were established to test a range of larger container sizes (Jobidon and others 2003). When measured 8 years after outplanting (fig. 7.1.3B), seedlings in the 340 cm^3 (20 in^3) containers were found to be the best and most economical stocktype in the absence of herbicides.

Customer preferences are also evidenced by regional trends in container type. It is cost prohibitive for a nursery to test all types of containers, so they typically use whatever is locally popular. Styroblock™ containers were developed in British Columbia and continue to be the most popular container type in the Pacific Northwest (Van Eerden 2002). In the Northeastern United States and Canada, however, hard plastic Ropak® Multi-Pots were the most popular container type and now are being replaced by Jiffy® cells (White 2003).

7.1.2.3 Genetic considerations

The third consideration of the Target Plant Concept concerns the question of genetics. Three factors should be considered: local adaptation, genetic diversity, and sexual diversity.

Local adaptation. Many native plants can be propagated by seeds collected on or near the project area. "Seed source" is an idea familiar to all forest nursery managers and reforestation specialists who know that, because plants are adapted to local conditions, seeds should always be collected within the local "seed zone." Container nurseries grow plants by seed zone, which is a three-dimensional geographic area that is relatively similar in climate and soil type (see Volume Six, Section 6.2.1.2). Local adaptation is not always considered in ornamental nurseries. For example, both native plant nurseries and ornamental nurseries grow Douglas-fir seedlings but the former distinguish between ecotypes (for example, variety *glauca*) and ornamental nurseries offer different cultivars (for example, 'Carneflix Weeping') (Landis 2001).

Seed source affects plant performance in several ways, especially growth rate and cold tolerance. In general, plants grown from seeds collected from higher latitudes or elevations will grow more slowly and tend to be more cold hardy during winter than those grown from seeds collected from lower elevations or more southern latitudes (St. Clair and Johnson 2003). Seed zone research has not been done on many native plants, but it is intuitive that the same concepts should apply. Therefore, it would be prudent to always collect seeds or cuttings from the same geographic zone and elevation in which the nursery stock is to be outplanted. With the increasing concern about global climate change, there are likely to be adjustments in seed transfer guidelines with the strategic goal of encouraging gradual adaptation based on the latest research (Millar and others 2007).

Genetic diversity. Target plants should also represent the genetic diversity present on the outplanting site. Again, future climate change should be considered, especially for long-lived tree species. To maximize genetic diversity in the resultant seedlings, seeds should be collected from as many different plants as possible. The same principles apply to plants that must be propagated vegetatively. Cuttings must be collected near the outplanting site to make sure they are properly adapted. Of course, collecting costs must be kept within reason, so the number of seeds or cuttings collected must be a compromise. Guinon (1993) provides an excellent discussion of all factors involved in preserving biodiversity when collecting seeds or cuttings, and suggests collecting from at least 50 to 100 donor plants.

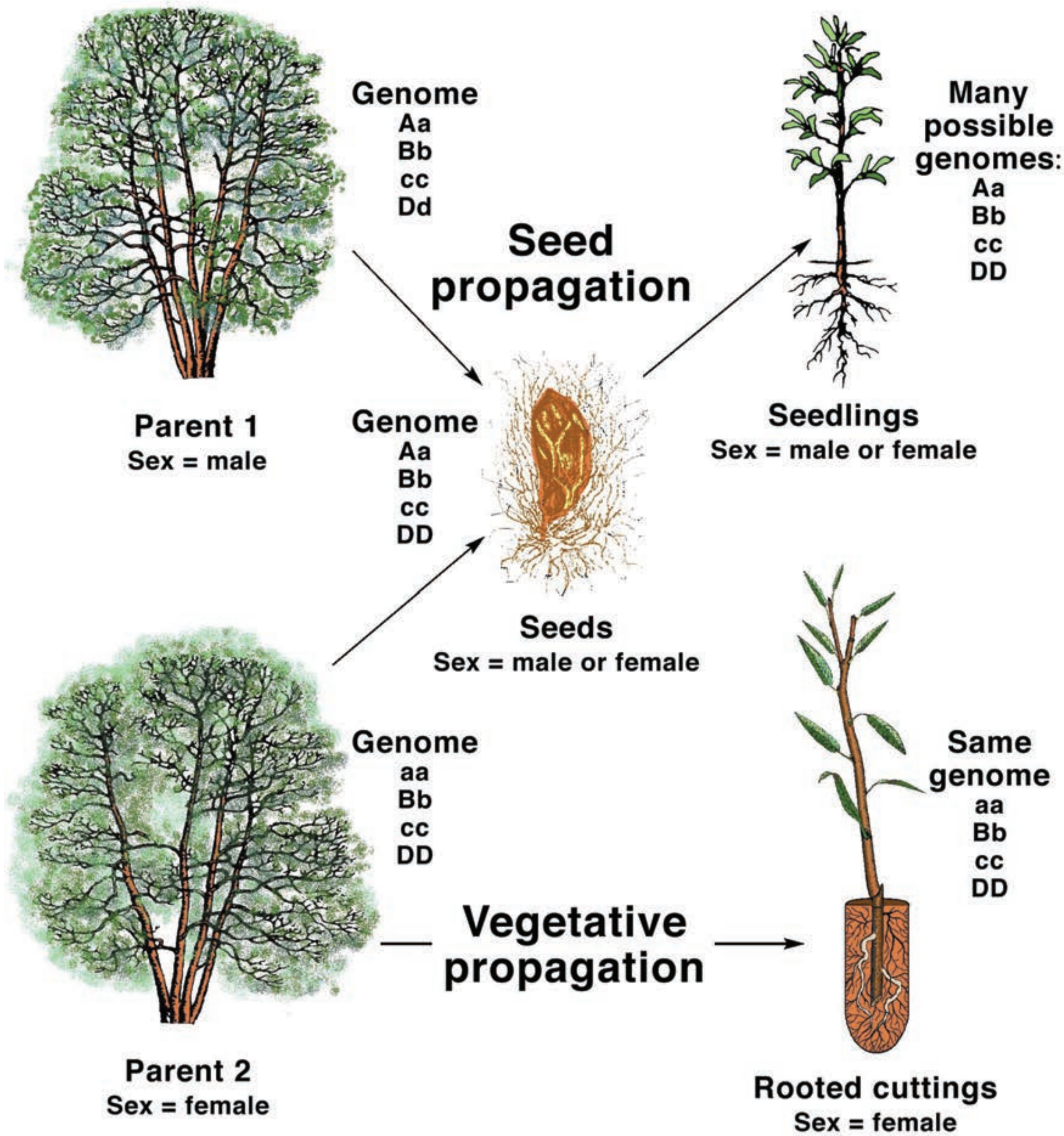

Figure 7.1.4—*The choice of whether to propagate by seeds or cuttings will affect the genetic diversity of the resultant crop. With dioecious plants, such as willows and cottonwoods, the sex of the parent plant must also be considered to make sure that the outplanting contains a mixture of both males and females (modified from Landis and others 2003).*

Sexual diversity. Dioecious plants, such as *Salix* and *Populus*, present another consideration, because all progeny produced by vegetative propagation will have the same sex as their parent (fig. 7.1.4). Therefore, when collecting cuttings at the project site, care must be taken to ensure that both male and female plants are approximately represented. Willows, cottonwoods, and aspen are sexually precocious so another option is to collect sexually mature cuttings from a broad genetic base that represents both sexes and root them in a nursery. Within 1 to 2 years the cuttings will flower and produce seeds. The seeds can then be sown into containers and the resultant seedlings will have a broad genetic and sexual diversity (Landis and others 2003).

7.1.2.4 Limiting factors on the outplanting site

The fourth consideration of the Target Plant Concept is based on the ecological “principle of limiting factors,” which states that any biological process will be limited by that factor present in the least amount. Each outplanting site should be evaluated to identify the environmental factors most limiting to survival and growth (fig. 7.1.5A). Foresters do this when they write prescriptions for each harvest unit, specifying which tree species and stocktype would be most appropriate (fig. 7.1.1).

On most reforestation sites, soil moisture is the limiting factor and target plant specifications often reflect this fact.

At northern latitudes or at high elevation, however, cold soil temperatures may be more significant than soil moisture. Access to these sites may be restricted by snow that may not melt until late June or even July (Faliszewski 1998; Fredrickson 2003). The melting snow keeps soil temperatures cool and this can be limiting as research has shown that plant root growth is restricted below 10 °C (50 °F) (fig. 7.1.5B) (Lopushinsky and Max 1990). A reasonable target plant for these sites could be grown in a relatively short container to take advantage of warm moist surface soils (fig. 7.1.5C) (Landis 1999), as is the case for high elevation reforestation sites in British Columbia (Faliszewski 1998).

Restoration sites pose interesting challenges when evaluating outplanting sites for limiting factors. For example, after a wildfire, soil conditions are often severely altered, whereas mining sites have extreme soil pH levels. Riparian restoration projects require bioengineering structures to stabilize streambanks and retard soil erosion before the site can be planted (Hoag and Landis 2001). In desert restoration, low soil moisture, hot temperatures, high winds with sand blast, and heavy grazing have been listed as limiting factors (Bainbridge and others 1992).

Animal predation and snow load can also be limiting factors on some outplanting sites, especially at high elevations in the mountains. Container Engelmann spruce (*Picea engelmannii*) seedlings of various diameter grades were outplanted on a mountainous site in northern Utah. After two seasons, seedlings with larger diameters had significantly higher survival than those with smaller ones. Stock with larger diameters showed less mortality from snow breakage or rodent depredation (Hines and Long 1986).

One potential limiting factor that deserves special consideration: mycorrhizal fungi. These symbiotic organisms provide their host plants with many benefits, including better water and mineral nutrient uptake. Reforestation sites typically have an adequate complement of mycorrhizal fungi that quickly colonize outplanted nursery stock, whereas many restoration sites do not. For example, severe forest fires or surface mining eliminate all soil microorganisms, including mycorrhizal fungi. Therefore, plants destined for such sites should be inoculated with the appropriate fungal symbiont before outplanting. (See Volume Five, Chapter 2, for a complete discussion of mycorrhizae).

These examples demonstrate why nursery managers must work closely with plant customers to identify which environmental factors will be most limiting on each outplanting site. Through such discussions, specifications for the best target plant material can be designed to maximize survival and growth under specific site conditions.

7.1.2.5 Timing of the outplanting window

The outplanting window is the period of time in which environmental conditions on the outplanting site are most favorable for survival and growth of seedlings or rooted cuttings. The outplanting window is usually defined by limiting factors and, as discussed in the previous section, soil moisture and temperature are the usual constraints. In most of the continental United States and Canada, nursery stock is outplanted during the rains of winter or early spring when soil moisture is high and evapotranspirational losses are low (fig. 7.1.6). Obviously, the specific dates of the winter outplanting window will change with latitude and elevation, being earlier in the south and at low elevations and later farther north and at higher elevations.

One important advantage of container plants is that they can be sown at different dates and then cultured to be physiologically conditioned for outplanting during different times of the year. For the traditional outplanting windows of winter or early spring, plants can be harvested and hot-planted or cooler-stored for a few weeks until the outplanting site is ready (fig. 7.1.7A). As mentioned in the previous section, high elevation or boreal sites are challenging because they cannot be accessed during the typical midwinter outplanting window. Outplanting during the fall has been tried for decades with varying results. In recent years, however, interest in fall outplanting has been renewed, which is primarily due to the availability of properly conditioned container stock (Fredrickson 2003). In the Southeastern United States, the traditional outplanting window for loblolly pine is during the winter but container stock can be outplanted in the fall if hardened with shortened photoperiod in a greenhouse or exposed to naturally cooler temperatures in an outdoor compound for 6 weeks (Mexal and others 1979).

Summer outplanting is a relatively new practice that developed in the boreal regions of Canada (Revel and others 1990) and has since found some application at high elevation sites in the Rocky Mountains (Scott 2006).

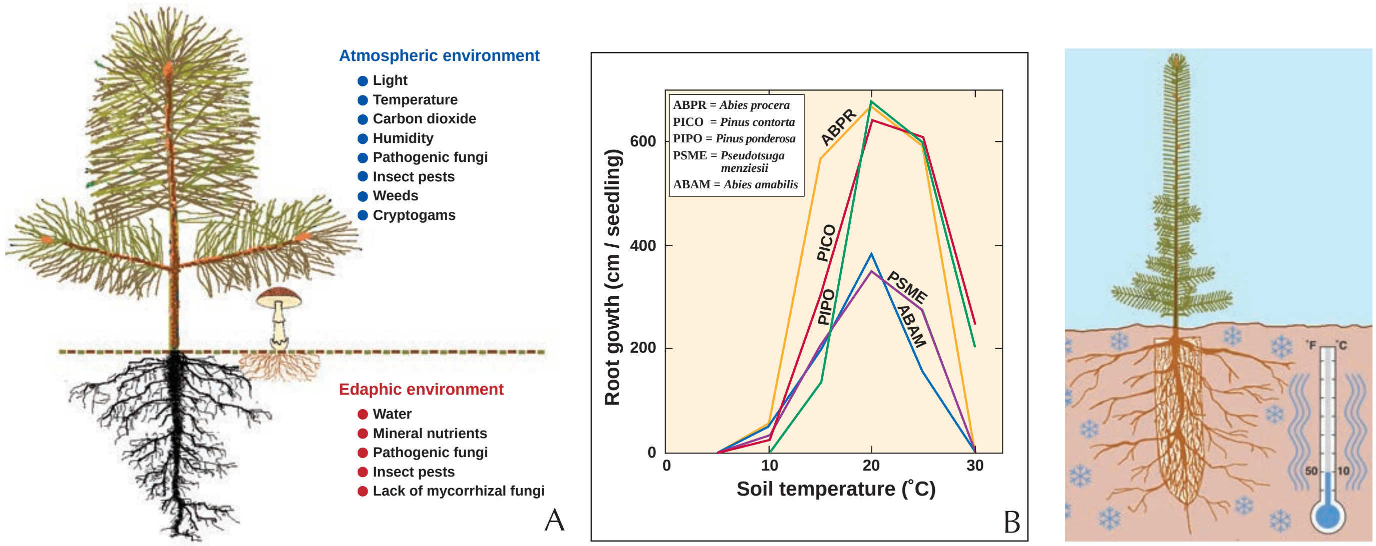

Figure 7.1.5—*A key part of the Target Plant Concept is to evaluate which environmental factors may be limiting on the outplanting site (A). At high elevations and latitudes, spring soil temperatures are cold and research has shown that roots of many commercial conifers do not grow appreciably below 10 °C (50 °F)(B). Therefore, target plants for these sites should have a relatively short, compact root system to take advantage of the warmer temperatures in the surface soil layers (C) (B, modified from Lopushinsky and Max 1990).*

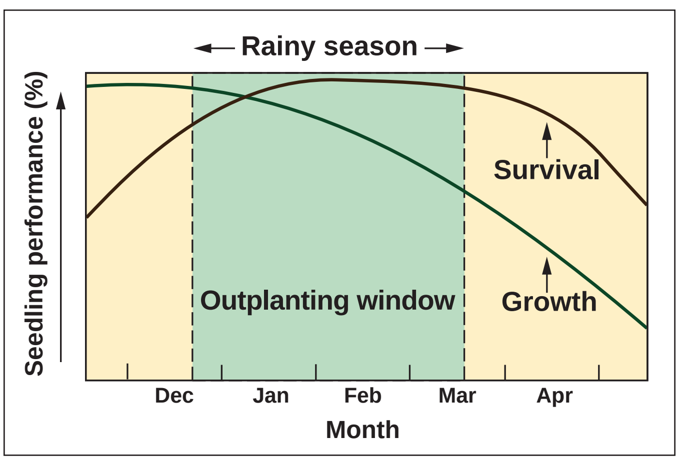

Figure 7.1.6—*A critical component of the Target Plant Concept is the "outplanting window," which is defined as the period of time in which plant survival and growth are optimal for that particular site. In much of the United States, the outplanting window is during the rainy period of midwinter (modified from South and Mexal 1984).*

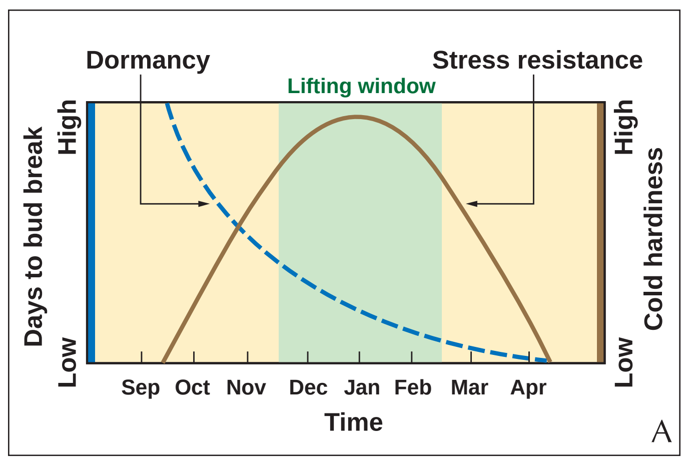

Figure 7.1.7—*Container plants can be grown to meet the target requirements for a variety of outplanting windows. They can be harvested at their peak of physiological quality for the traditional midwinter window (A), or be specially cultured for summer or fall outplanting (B).*

B

Target plant characteristics are significantly different for spring versus summer or fall outplanting (Grossnickle and Folk 2003). Because they are less cold hardy and stress resistant, plants for summer and fall outplanting must be handled more carefully during shipping and onsite storage.

7.1.2.6 Outplanting tools and techniques

Each outplanting site has an appropriate tool; therefore tools and outplanting techniques must be considered in the Target Plant Concept. All too often, foresters or restoration specialists develop a preference for a particular implement because it has worked well in the past. However, no one tool will work under all site conditions. Although outplanting tools are discussed in detail in Chapter 7.6, a couple of examples of how outplanting tools and techniques can affect target plant specifications are mentioned here.

Soon after development of the first container plants, special implements were designed to outplant them (Hallman 1993). Dibbles were constructed in the exact same size and shape as the container plugs and the Pottiputki was designed to plant paperpot plants (fig. 7.1.8A). Nursery stock that is outplanted mechanically imposes unique restrictions because the target plant must conform to the size and shape of the handling equipment. Plants used in machine-powered planting equipment must have stem diameters that fit the holding clips, and root systems must not be longer than the depth of the furrow. The newest and most sophisticated machine-powered planting equipment requires plants of a size and shape that can be pneumatically loaded into planting heads (fig. 7.1.8B). So, where mechanical planting is used, the size and shape of the target plant must match the type of outplanting tool as well as biological conditions on the outplanting site.

New outplanting tools are continually being developed. Specially modified hoedads called "plug hoes" are now available for container stock. Again, nursery managers must work closely with reforestation or restoration project managers to make certain that their target plants can be properly outplanted in the soil conditions on the project site. The "tall pots" used in many restoration projects require specialized outplanting equipment. The Expanded Stinger uses an articulated planting head to place tall-pot seedlings or cuttings in compacted soil or even rock (Steinfeld and others 2002) (fig. 7.1.8C).

Figure 7.1.8—*The type of outplanting tool has a significant effect on the target plant. Hand-planting tools, such as the Pottiputki (A), were developed to handle paperpot seedlings, one specific type of container stock. With mechanical planting machines (B), plants must be grown in a particular size and shape to fit the handling system. The special stocktypes needed for restoration projects require innovative new outplanting equipment, such as the Expanded Stinger, which was developed for tall pots (C).*

7.1.3 Field Testing the Target Plant

Properly applied, the Target Plant Concept is a collaboration among nursery managers and their customers. At the start of any planting project, the customer and the nursery manager should agree on certain morphological and physiological specifications. This prototype target plant is grown in the nursery and then verified by outplanting trials that monitor survival and growth for up to 5 years (fig. 7.1.9).

Monitoring plant survival and growth during the first few months after outplanting is critical because problems with stock quality show up soon after outplanting. Problems with poor planting or exposure to drought conditions take longer to appear; plants exhibit good initial survival but gradually lose vigor and perhaps die. 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 to 5 years 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 fine-tune the target specifications for the next crop.

For example, the Oregon State University Nursery Technology Cooperative is conducting outplanting trials of 1-year-old stocktypes on two fire restoration sites in southwestern Oregon (Nursery Technology Cooperative 2005). The Timbered Rock site in the Cascade Mountains is much drier than the Biscuit site in the Coast Range. In terms of survival, the Styroblock™ container performed much better than the transplants at Timber Rock, whereas little difference was noted on the wetter Biscuit site (table 7.1.2). The container stocktype also grew much better at both sites, but especially so at Timbered Rock where grass competition was severe. In fact, the severe moisture stress caused by the grass resulted in a negative stem growth for the two transplant stocktypes. After 3 years, however, the container stocktype exhibited severe chlorosis and slower growth rates, which demonstrates the need for repeated monitoring to accurately assess seedling and stocktype performance.

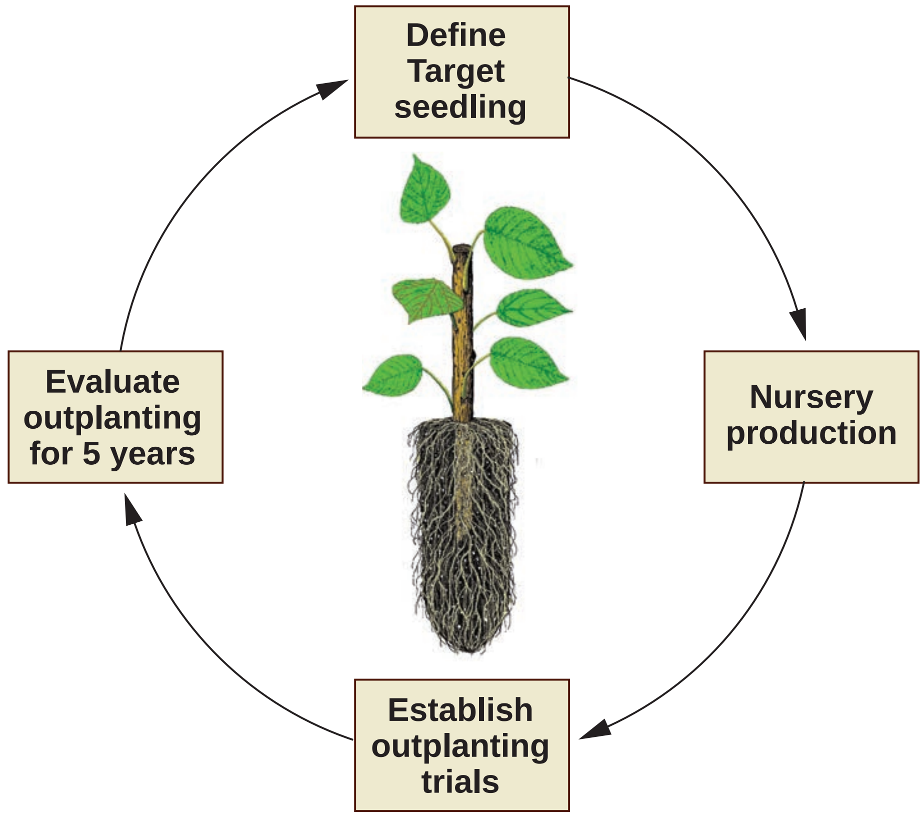

Figure 7.1.9—*The target plant is not a fixed concept, but rather must be continually updated with information from outplanting trials.*

Table 7.1.2—*Outplanting performance of Douglas-fir stocktypes on different outplanting sites after one growing season*

Stocktype	**Survival (%)**	**Height growth (cm)**	**Stem diameter growth (mm)**
Timbered Rock Fire— Oregon Cascade Mountains			
1+1 bareroot transplant	14 c*	4.2 b	– 0.6 b
Q-plug container transplant	39 b	2.6 b	– 0.3 b
Styroblock™ container (246 cm^3)	87 a	12.0 a	0.8 a
Biscuit Fire— Oregon Coastal Mountains			
1+1 bareroot transplant	98 a	4.6 b	0.5 b
Q-plug container transplant	98 a	7.0 a	0.5 b
Styroblock™ container (246 cm^3)	99 a	7.5 a	1.1 a

* Different letters in each column represent statistical differences at the $P = 0.05$ level.

7.1.4 Summary

The Target Plant Concept is a relatively new but effective way of looking at reforestation and restoration. It emphasizes that plant quality must be defined on the outplanting site, and that there is not one universal best stocktype. In particular, the Target Plant Concept emphasizes that successful outplanting projects require good communication between the plant user and the nursery manager. The Target Plant Concept should be viewed as a circular feedback system in which information from the outplanting site is used to define and refine the best type of plant for each project. Practical considerations for implementing a nursery program based on the Target Plant Concept can be found in Rose and Haase (1995).

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