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# The Target Plant Concept—A History and Brief Overview

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**Abstract:** The target plant concept originated with morphological classification of conifer nursery stock in the 1930s, and the concept was enhanced through physiological research and seedling testing towards the end of the century. Morphological grading standards such as shoot height, stem diameter, and root mass are the most common use of the target plant concept, and some physiological grading standards are also being operationally implemented by nursery workers and seedling users. Since 2000, the concept has been expanded to include all types of plant materials, including seeds, cuttings, or wildlings, as well as traditional nursery stock. Because these native plant materials are being outplanted on harsh, severely disturbed sites, this more comprehensive native plant materials concept also involves environmental conditions on the project site.

**Keywords:** nursery, reforestation, restoration, seedling, native plant

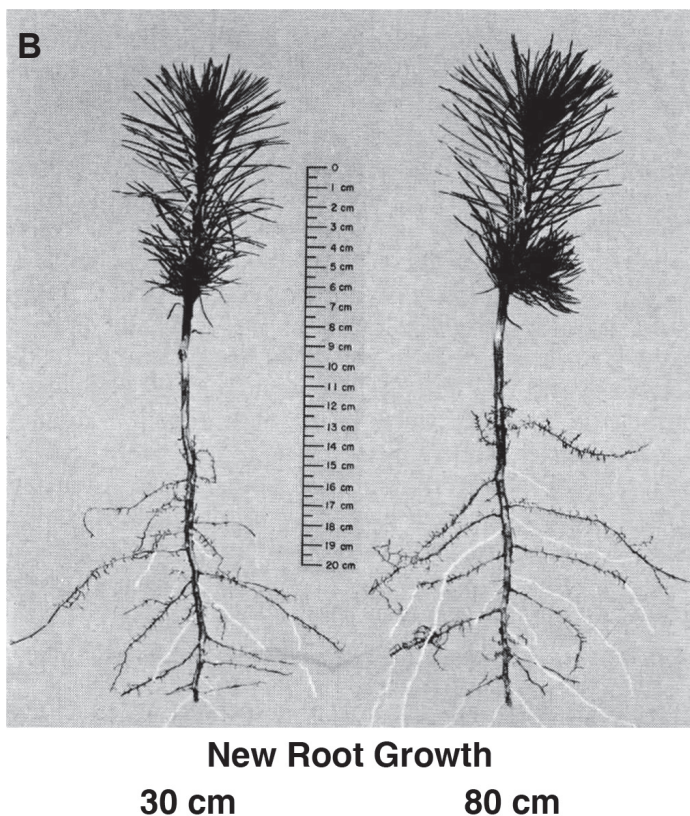
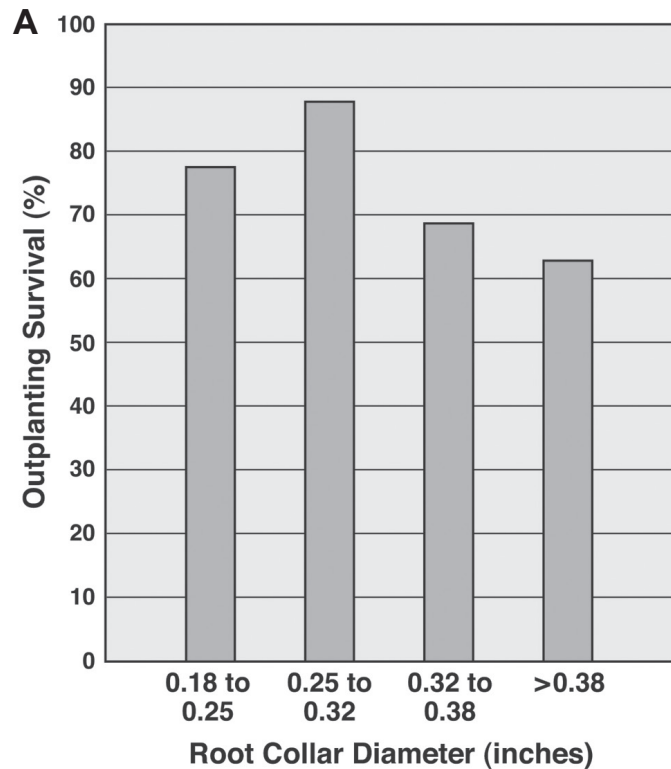
The term “target seedling” has become a standard part of nursery and reforestation jargon, and this is the second symposium on this subject. Although we don’t know the exact time when the target seedling was first used, the term has undergone constant refinement over the years. In researching published literature, we can examine the development of the target seedling concept in three chronological phases.

## Phase 1: Morphological Specifications

Since the early 1900s, foresters and nursery managers have attempted to measure the quality of nursery stock by morphological characteristics such as shoot height and stem diameter, oven-dry weight, and relative size comparisons, such as shoot-to-root ratio. These morphological targets have helped growers manage their crops and fine tune cultural practices; in addition, these physical attributes served as grading specifications after harvesting. In the 1930s, a visionary USDA Forest Service scientist named Phil Wakeley proposed three morphological grades of southern pine (*Pinus* spp.) seedlings, and developed a system of seedling quality testing by monitoring survival and growth after outplanting (Wakeley 1935). One of the morphological measurements most consistently related to survival and growth after outplanting was stem diameter at the root collar (Figure 1A). After years of testing, however, he realized that grading seedlings using morphology alone was often ineffective in predicting outplanting performance (Wakeley 1954). Morphological grading specifications are still the most common application of the target plant concept and stem diameter at the root collar (“caliper”) is the most consistently correlated to outplanting performance (Mexal and Landis 1990).

## Phase 2: Physiological Research Leads to Seedling Quality Testing

Wakeley’s research prompted him to develop the concept of physiological grades and to conclude that mineral nutrient content, stored carbohydrates, or water tension were the most likely differences between the grades (Wakely 1948). This observation showed amazing foresight in describing the phenomenon that we now call “root egress” and consider essential to outplanting success.



**Figure 1.** (A) Wakeley developed a series of morphological grades for southern pines by relating them to survival and growth after outplanting (modified from Wakeley 1954). (B) Root growth capacity was used to create physiological grades of ponderosa pine seedlings; these morphologically identical seedlings had significantly different amounts of new root growth (modified from Stone and Jenkinson 1971).

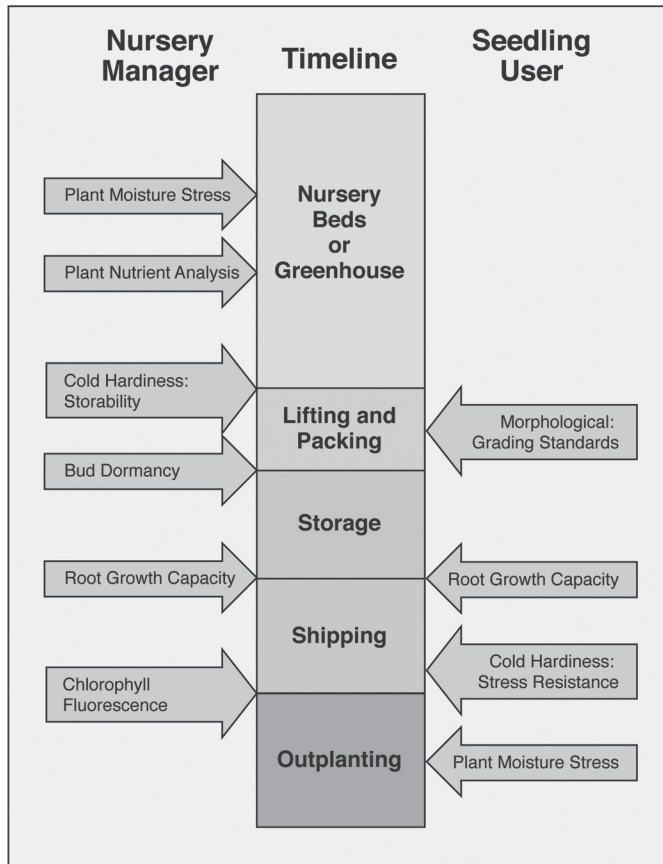
*High physiological quality of southern pine seedlings seems to improve survival principally by insuring that the water intake of the seedlings immediately after planting equals or exceeds their water loss. The probability is great that in many cases it insures this favorable water balance by enabling the seedlings to extend new root tissue into the soil of the planting site within the first few days after planting (Wakeley 1954).*

The first person to develop an actual seedling testing procedure was Edward Stone, a forestry professor at the University of California at Berkeley. He pioneered the root growth capacity test (RGC) in the 1950s and first presented the idea of seedling quality testing to a western forest nursery association meeting (Stone 1954). He observed that the ability to grow new roots after outplanting was somehow related to seedling quality (Figure 1B) and the current RGC test is the result. RGC was later used to develop a series of physiological grades for bareroot ponderosa pine (*Pinus ponderosa*) seedlings (Stone and Jenkinson 1971).

In the 1970s and 1980s, there was a tremendous surge in the amount of research on seedling physiology. The first symposium on planting stock quality was held in New Zealand in 1979 and produced some of the classic articles on seedling quality testing (Gadgil and Harris 1980). It was at this symposium that one of the most concise definitions of seedling quality was coined, that is, seedling quality is “fitness for purpose” (Ritchie 1984). This idea that plant quality is defined on the outplanting site and not at the nursery is one of the pillars of the target seedling. The proceedings from a workshop on evaluating seedling quality at Oregon State University have become one of the primary references for seedling quality testing (Duryea 1985).

This phase culminated in the first Target Seedling Symposium (Rose and others 1990), which included over 25 articles on both morphological and physiological aspects of seedling quality. By this time, the term target seedling was well accepted in the nursery and reforestation field and was most commonly used to designate planting stock specifications, especially plant height, stem diameter, and shoot-to-root ratios. More attention was also being paid to the root system and techniques such as root volume were being tested (Haase and Rose 1990). While seedling quality tests such as RGC and plant moisture stress were commonly used, there was still no operational use of seedling physiological grades. This symposium also introduced the physiological treatment of short-days or “blackout” (Eastham 1990), which has subsequently been specified in growing contracts for container seedlings.

In the 20 years since the first Target Seedling Symposium, the list of seedling quality tests has steadily increased and several firms have offered testing on a fee basis (Landis and others 2010). Traditional tests, such as RGC and cold hardiness, are still the most popular with both nurseries and seedling users (Figure 2). Testing plant moisture stress at different stages of the harvest-to-outplanting process can ensure that plant stress is minimized. Chlorophyll fluorescence and root electrolyte leakage tests may be used immediately after unexpected stresses. Cold hardiness testing can be done to determine proper harvesting windows and to ensure that stress resistance is still high prior to outplanting. In reality, a combination of two or more seedling quality tests may prove to better predict



**Figure 2.** Seedling quality tests can be done by both nursery managers during the production cycle or by nurseries and seedling users during harvesting, shipping, and outplanting (from Landis and others 2010).

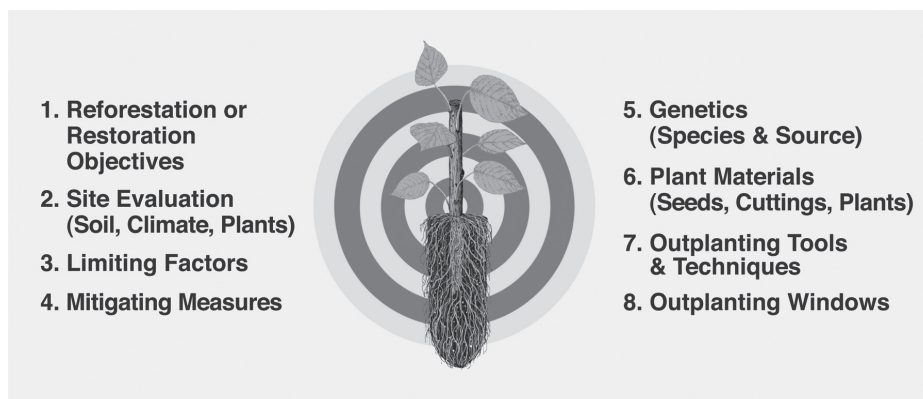
outplanting performance. For example, an index using RGC and chlorophyll fluorescence proved to be highly correlated with survival and growth of conifer seedlings (L’Hirondelle and others 2007).

### Phase 3: Expanding the Target Plant Concept to Restoration of Disturbed Lands with Native Plants

Starting in the 1990s, nurseries began to produce a wider variety of native plant species for ecological restoration projects. Existing forest and conservation nurseries expanded their product line from a few traditional tree species to include grasses, forbs, woody shrubs, and non-commercial trees (Landis and others 1993). To accommodate this new emphasis, the target seedling concept was expanded to include all types of plant materials, that is, seeds, seedlings, cuttings, and even plants salvaged from project sites (wildlings). The target plant concept was one of the key driving forces used to develop the Roadside Revegetation Manual (Steinfeld and others 2007) and subsequent training sessions. Initially, the target plant concept was defined by six aspects (Landis 2001); because these native plants would be outplanted on harsh, severely-disturbed sites, site evaluation and mitigating measures were added (Figure 3).

### Reforestation or Restoration Objectives

The reason non-commercial native plant materials are being used has an overriding influence. In traditional reforestation, commercially valuable tree species that have been genetically improved for fast growth are outplanted with the ultimate objective of producing saw logs or pulp. The fact that restoration projects use a different variety of plant materials radically changed the target plant concept. Restoring severely disturbed lands generates a new list of project objectives, including soil erosion prevention or the elimination of exotic weeds.



**Figure 3.** Considering all types of native plants for disturbed site restoration, the target plant materials concept consists of eight aspects.

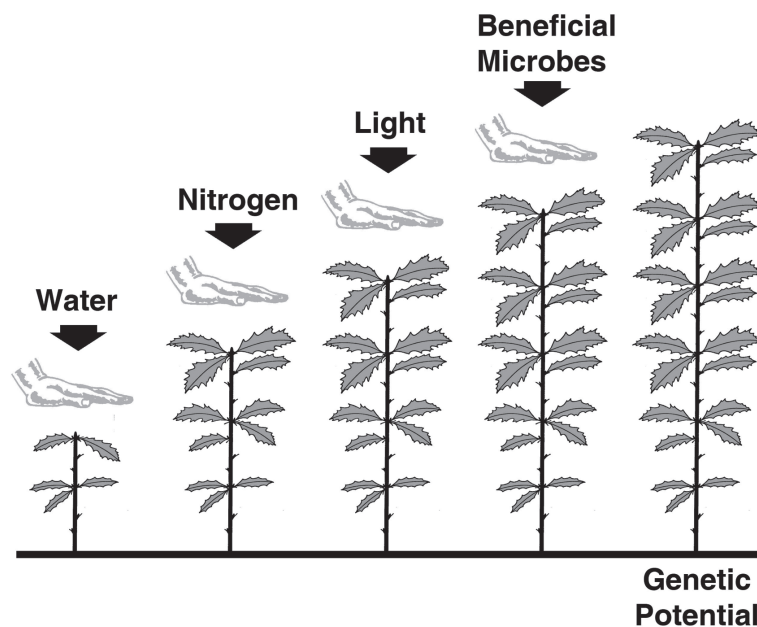


## Site Evaluation—Soil, Climate, Plants

Whether for reforestation or restoration, the project site should be comprehensively described early in the process. Using a map of the project area, the soils should be evaluated and an overlay made of the various soil types. Soil survey maps are available from the USDA Natural Resources Conservation Service Web Soil Survey (URL: <http://websoilsurvey.nrcs.usda.gov/app>). Climatic information can be obtained from local weather stations or online from the Western Regional Climate Center that has 2800 weather stations in the western US (URL: [www.wrcc.dri.edu](http://www.wrcc.dri.edu)). A trained botanist should conduct detailed surveys of which plants are currently found on disturbed and undisturbed reference sites in the project area. A wealth of botanical information can be found on-line; Ecoshare is one example that is a joint effort of the USDA Forest Service and the USDI Bureau of Land Management (URL: <http://www.reo.gov/ecoshare/index.asp>).

## Limiting Factors

After all site information is compiled and evaluated, the next step is to determine which environmental factors on the project site are most limiting to plant establishment and growth. Because they are typically severely disturbed, restoration sites are particularly difficult to revegetate due to soil loss or damage. A whole array of atmospheric and edaphic factors can be limiting, but soil moisture and temperature are the most common factors to consider. There are typically more than one limiting factor, and they should be ranked in order of severity. Limiting factors are cumulative and sequential, that is, once one factor is overcome, another will typically become limiting (Figure 4).



**Figure 4.** The idea of limiting factors is critical to the target plant materials concept because it helps characterize environmental conditions on the outplanting site.

## Mitigating Measures

Once limiting factors have been identified and ranked, the best and most cost effective way to mitigate their effects must be determined. Many mitigating measures will affect more than one limiting factor, and their effectiveness will depend on the site characteristics and project objectives. For example, mulches of organic matter are often used to prevent surface soil erosion as well as retard soil moisture loss. With roadside revegetation trials, hydromulch was found to be most effective on the western side of the Cascade mountains where there was plenty of precipitation. In contrast, fiber mulches worked better in eastern Oregon where soil moisture is especially limiting (Steinfeld 2010).

## Genetics—Species and Source

The question of which native plant species should be used on a restoration project is usually dependent on project objectives as well as the results of vegetation surveys of similar sites. “Workhorse” species are locally adapted native plants that are locally common, have broad ecological amplitude, and are relatively easy to propagate (Steinfeld and others 2007). Once the species have been selected, the question becomes one of source; local sources are preferred to ensure that plants are adapted to the environment on the project site. Seed zones are available for most commercial tree species, but guidelines for shrubs, grasses, and forbs are still being developed. Most restorationists, therefore, require that plant materials be collected at or near the project site. When working with cuttings of dioecious species, such as willows or cottonwoods, the sex of the plant material is also a serious consideration to ensure that a good mix of male and female plants is established (Landis and others 2003).

## Plant Materials—Seeds, Cuttings, Plants

Compared to the original target seedling, this more expansive target plant materials concept includes all types of propagules used to establish plants on the project site. Seeds of grasses, forbs, and some woody shrubs are directly sown onto the site, whereas larger woody plants are typically grown as nursery stock and outplanted. In some cases, wildlings are harvested from the local area and transplanted onto the project site. In riparian restoration, both unrooted and rooted hardwood cuttings are extensively used. Cuttings collected on the project site are the primary propagules used to produce nursery stock, whereas streambank bioengineering utilizes live stakes and branched cuttings for structures such as wattles or vertical bundles (Hoag and Landis 2001).

## Outplanting Tools and Techniques

Unfortunately, many inexperienced foresters or restorationists don't consider how they are going to get their plants in the ground until the last minute. Seeds can be broadcast sown, drilled into the soil surface, or applied through hydroseeders. Unrooted cuttings are planted with dibbles or specialized equipment like the waterjet stinger (Hoag and others 2001). A wide variety of hand tools have been used successfully to outplant nursery stock. All too often, however, foresters or restoration specialists develop a preference for a particular implement because it has worked well in the past. Professional planters will choose the implement that gets plants into the ground as quickly as possible. Although this obsession with productivity is understandable, it can lead to serious problems with survival and growth. For example, dibbles work reasonably well on sandy soils, but they create a compacted soil layer that inhibits root egress in clay soils (Landis and others 2010). The pattern and spacing of outplanted seedlings is also a reflection of project objectives. Industrial forestry projects, where timber production is the primary objective, outplant the maximum number of trees per area in a regularly spaced pattern. Where ecological restoration is the objective, however, installing plants randomly or in random groups is more representative of natural vegetation patterns (Landis and Dumroese 2006).

## Outplanting Windows

Timing of the outplanting project is the final aspect of the target plant concept to consider, and it should be considered during the planning stage. The outplanting window is the period of time during which environmental conditions on the outplanting site are most favorable for survival and growth of the plant material. The main idea is to get the seeds, cuttings, or plants installed when the normally limiting soil moisture and temperature are at ideal levels. For instance, in the Pacific Northwest of the US, nursery stock is typically outplanted during the rains of winter or early spring. Fall outplanting is preferred on project sites where access is limited during the winter or spring. Summer and autumn outplanting with container plants is becoming more common at high elevation or latitudes, but the stock must undergo special cultural conditioning to ensure hardiness (Landis and Dumroese 2006).

## Summary

Basic precepts of the target plant materials concept can be summarized as follows:

- Nursery stock can be described by both morphological and physiological characteristics, but must be related to outplanting performance.
- The most common application of the target plant concept is the use of morphological attributes, such as shoot height and stem diameter, as grading specifications.
- Target plant characteristics can only be described on the outplanting site, not in the nursery.
- Plant users must be involved in establishing objectives and setting specifications.
- Target plant specifications must be tested in the field and results of outplanting trials used to refine the concept.

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