The Target Seedling Concept: The First Step in Growing or Ordering Native Plants

Thomas D. Landis
541-858-6166
tdlandis@fs.fed.us
National Nursery Specialist
USDA Forest Service
Cooperative Programs
2606 Old Stage Road
Central Point, OR 97502-1300

Abstract

The target seedling concept was developed for reforestation but can and should be applied to the propagation and use of native plant materials. The basic idea is that seedling quality is determined by outplanting performance (survival and growth) rather that characteristics or standards measured at the nursery. This means that there is no all-purpose plant, but that each project will require different types of plant materials including seeds, nursery stock, unrooted cuttings, and bulbs or rhizomes. The target plant materials concept is not static but must be continually updated and improved with feedback from outplanting projects.

Key words

restoration

Introduction

The first native plant nurseries in North America were forest tree nurseries which were established in the early 1900s. Back then, the entire process was very simple: nurseries produced the seedlings which were then shipped for outplanting. Foresters took what they got and there wasn't much choice. In those days, tree planting was a mechanical process of getting the seedlings in the ground in the quickest and least expensive manner. Not much thought was given to seedling quality, different stock types, or the possibility of matching seedlings to outplanting site conditions.

Proceedings of the Conference: Native Plant Propagation and Restoration Strategies. Haase, D.L. and R. Rose, editors. Nursery Technology Cooperative and Western Forestry and Conservation Association. December 12-13, zoo! . Eugene, OR.

In the last 25 years, however, more science has been infused into the process. New research into seedling physiology and better-educated customers have revolutionized traditional concepts of reforestation. We now understand much more about how tree seedlings function--both in the nursery and after outplanting. In particular, the advent of the container seedling showed the importance of nursery cultural practices and vividly demonstrated important concepts like hardiness and dormancy. Today's seedling customers are very well educated, they know what they want, and they have many choices.

The Target Seedling Concept

The target seedling is a relatively new concept but the basic idea can be traced back to the late 1970s and early 1980s when new insights into seedling physiology were radically changing nursery management. A literature search of my Forest Nursery Notes database found nothing published on "target seedlings" before 1990. In that year, however, the Western Forest Nursery Association conducted a symposium to discuss all aspects of the target seedling, and the resultant proceedings are still a major source of information on the subject (Rose et al. 1990).

One basic tenet of the target seedling concept is that seedling quality is determined by outplanting performance or how the seedlings will be used-"fitness for purpose" (Ritchie 1984). Although it may sound rather intuitive and obvious, this represents a major change in the way nursery stock is grown. For example, most people consider a Douglas-fir *(Pseudotsuga menesii)* seedling as a generic product that only varies in stock type and price. Forest nurseries distinguish between ecotypes (e.g. variety *glauca)* and ornamental nurseries offer different cultivars (e.g. "Carneflix Weeping"). Until the target seedling concept was introduced, however, nurseries did not grow seedlings for specific outplanting sites. Now, we realize that seedling quality cannot be merely *described* at the nursery, it can only be *proveu* on the outplanting site. The target seedling concept emphasizes that there is no such thing as an "all-purpose" tree seedling. A nice looking seedling at the nursery will not survive and grow well on all sites.

Although originally developed for reforestation, the target seedling concept should also be applied to native plant propagation and outplanting. Therefore, my objective is show how these concepts can be used to define the best type of plant material for any outplanting project.

Defining Target Plant Materials

The process consists of six sequential, but interrelated steps (Figure 1):

1. Project objectives

It is critically important to define the reasons why plant materials are needed before the project is even started. 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 target plant materials for a restoration project will be radically different, however, as commercial products are not a consideration. For example, the objectives of a watershed restoration project might consist of stopping erosion, stabilizing the stream bank, and ultimately

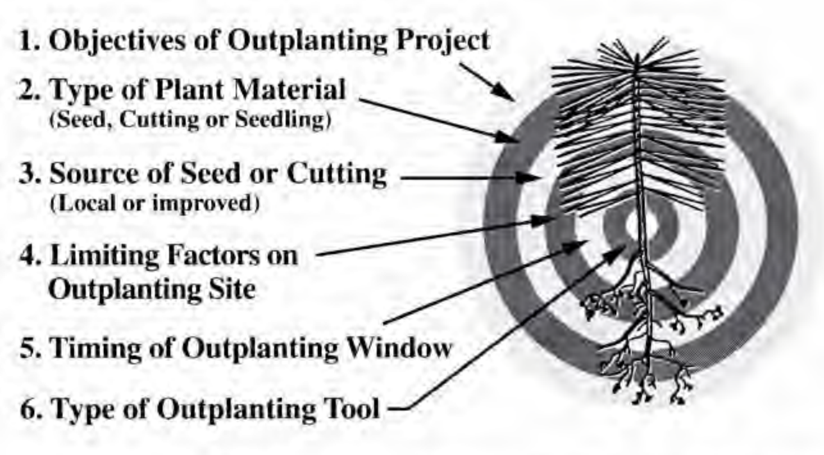

Figure 1 - The process of defining the target plant materials for a specific outplanting site consists of six steps.

restore a functioning plant community (Figure 2). This is an interesting example because the target plant materials for riparian restoration would include hardwood cuttings for bioengineering structures such as brush mattresses, wattles, and vertical bundles as well as nursery stock (Hoag and Landis 2001).

Fire restoration projects will have different objectives depending on the plant community and the ultimate use of the land. The project objectives for a burned rangeland might be to stop soil erosion, replace exotic weed species with natives, and establish browse plants for deer or elk. Target plant materials for this project might include a direct seeding of native grass and forbs, followed by an outplanting of woody shrub nursery stock. For a burned commercial forest, however, the plant materials would be grass seed 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 only be found in 14 populations in a small geographic area in Kentucky (Baskin et al. 2000). Fortunately, this plant is relatively easy to propagate from seed and grows well in greenhouses, so the target plant material would be container seedlings.

Restoration objectives need to be clearly defined; however, the terminology can be rather intimidating with technical terms such as enhancement, rehabilitation, reclamation, and revegetation. See Newton (1993) for a comprehensive discussion of these terms and how they relate to restoration project objectives.

2. Types of plant material

Native plant restoration projects use a variety of different plant materials and establishment techniques: transplanting wildlings, direct sowing of seeds, outplanting nonrooted cuttings or rhizomes, and propagating and outplanting of nursery seedlings or rooted cuttings. Transplanting wildlings consists of digging up and moving existing plants from adjacent sites and outplanting them in the project area. Besides being expensive due to the labor involved, this technique has little merit in ecological restoration unless the operation is carried out for the purpose of salvaging unique or rare plants from an area destined to be destroyed (Landis et al. 1993).

Plant materials are introduced into most restoration projects by direct seedling, planting of nonrooted hardwood cuttings, or outplanting bareroot or container nursery stock (Table I).

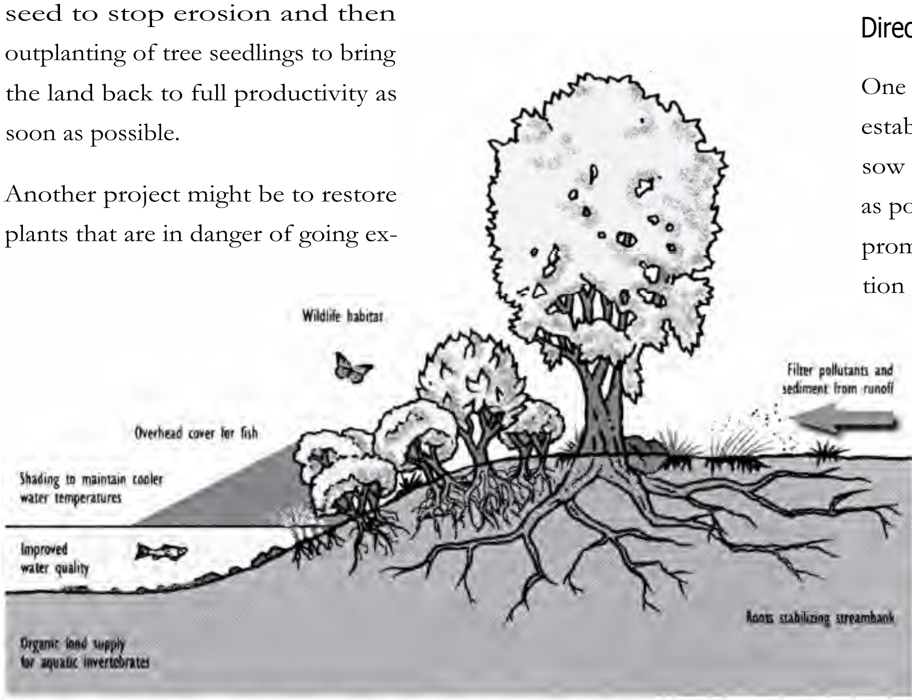

Figure 2 - Restoration project objectives are the first step in defining target plant materials.

Direct seeding

One of the most obvious methods for establishing plant communities is to sow seeds of as many native species as possible, and then hope for rain to promote rapid and uniform germination and establishment. Seeds can be broadcast sown by hand or machine drilled. The effectiveness of direct seeding varies with the species of plants, the harshness of the site, and the objectives and time frame of the planting project. The principal advantages of direct seeding are that it is inexpensive, relatively easy, and allows seedlings to develop a natural

Table 1 - Consequences of Using Different Types of Plant Materials in Restoration Projects

Consequence	Seeds	Nonrooted Cuttings	Nursery Stock
Efficient Use of Plant Material	No	No	Yes
Cost of Establishment	Low	Moderate	High
Ability to Establish Harsh Sites	No	No	Yes
Option of Using Specific Genotypes	Yes	Yes	Yes
Precise Scheduling of Establishment	No	No	Yes
Control of Species Diversity	No	Some	Yes
Control of Plant Spacing	No	Some	Yes

Modified from Landis et al. (1993)

root system. However, there are many drawbacks (Table 1). Native plant seeds from the proper seed source are often difficult to obtain or are very expensive, some species do not produce adequate seed crops each year, and the seeds of others, such as the white oaks *(Quercus* spp.), do not store well. Seeds of many diverse species require special cleaning and processing before they can be sown. Even if the proper seeds can be obtained and properly distributed over the site, predation from birds and rodents, competition from weed species, and unpredictable weather often reduce establishment success. And finally, with direct seeding, it is difficult to control species composition and plant spacing over the project area (Landis et al. 1993).

Direct seeding is generally recommended for grasses and forbs, although certain woody shrubs and trees can also be established under some conditions. In California, direct seeding of native oaks has been quite successful and the Department of Fish & Game has direct-seeded alkali bullrush *(Scirpus robustus)* for restoration of wetland wildlife habitat in the Delta. Reduction of weed competition and protection from seed predation were certainly key factors in the success of these projects (Landis et al. 1993).

Planting nonrooted cuttings

Many riparian and wetland species can be successfully propagated on site by collecting cuttings and planting them without roots. The term "stem cutting" generally referring to traditional hardwood cuttings but also includes rhizomes and tubers, which are modified underground stems. Specialized roots, such as bulbs and corms, can also be used to propagate some plants. Under ideal conditions, planting nonrooted cuttings can be a very cost effective means for establishing certain vegetation types. There are several limitations, however (Table I). Because this is a type of vegetative propagation, care must be taken to sample from a variety of individual plants and populations so that adequate genetic and sexual diversity will be represented. Since vegetatively propagated plants retain the sexuality of the parent, care must be taken to collect from both male and female plants to insure future seed production.

Nonrooted hardwood cuttings are prepared from long whips collected from shrubs or trees on the project site or from stock plants at a nursery. If a large number of cuttings will be needed for several years, it might be wise to establish stooling beds at a local nursery. Whips should be collected during the dormant season when the potential new root formation is highest. They are cut in sections which range from 12 to 24 inches (30 to 61 cm) in length and 3/8 to 3/4 inch (10 to 19 mm) in caliper. When planted properly in moist soil and under favorable conditions, cuttings will form new roots which follow the receding water table down as the young plant develops during the first growing season.

An interesting type of hardwood cutting sometimes used in riparian restoration projects is called the stump or pole cutting (Hoag and Landis 2001). These poles are often six feet (1.8 m) in length and 8 to 12 inches (20 to 30 cm) in diameter and are obtained by cutting the major branches or stems of existing cottonwood or willow trees. The key to success with these extremely large nonrooted cuttings is to plant them deep enough so that the butt end reaches the water table (Figure 3). The soil must also be coarse enough to allow enough air exchange at these depths to support adequate root growth. Unfortunately, this is not always the case. If the bottom of the pole cutting loses contact with the ground water or if soil conditions are not favorable for root production, shoots called "watersprouts" will form

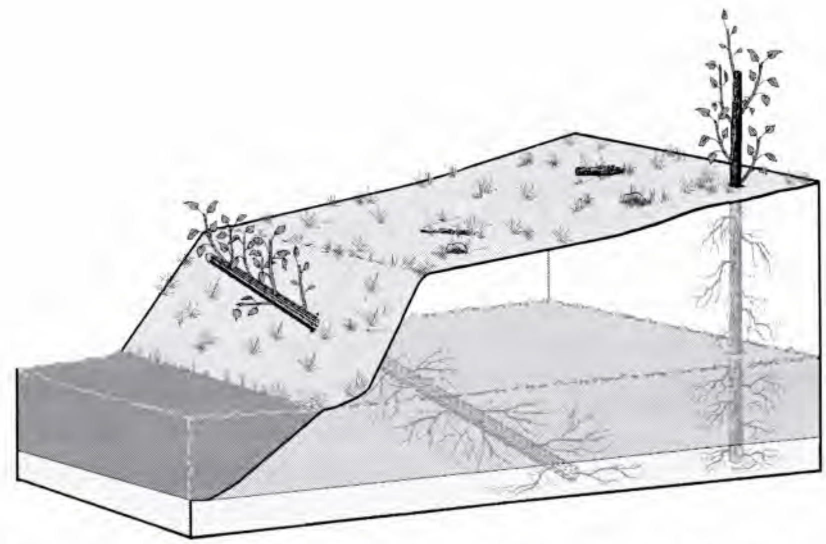

Figure 3 - Willows, cottonwoods and other riparian trees and shrubs can be establishing by pole plantings that are long enough to always reach ground water (from Hoag and Landis 2001)

but quickly wither. Another drawback to the use of pole cuttings is the obvious impact to the "donor" or stock plants from which the cuttings were obtained. However, this is not a problem when collecting poles from special stooling beds in nurseries.

Rhizomes, tubers, bulbs and some types of root sections are used for the vegetative propagation of certain grasses and wetland plants. Grass and sedge rhizomes and root sections have been successfully used for wildland outplantings, such as a prairie restoration project at Jepson Prairie in California (Landis et al. 1993). Because of difficulties with seed dormancy, the Mason State Nursery in Illinois produces rooted cuttings and root divisions of several species of prairie forbs, woodland understory and wetland plants (Pequinot 1993). The advantages and drawbacks for rhizomes and root sections are the same as those for nonrooted hardwood cuttings (Table 1).

Nursery stock

For projects where rapid and complete establishment of the desired plants is critical, outplanting seedlings or rooted cuttings that were raised at a nursery is usually the best method. Nursery stock is the most efficient establishment method when seeds or cuttings are in a short supply or are expensive (Table 1). When done properly, the high rates of success make nursery stock one of the most appropriate methods for natural resource planting projects. Nursery production can be coordinated with the project timetable, so that the target species will be available at the proper size and in the outplanting window. When forced to meet human time scales, natural reproduction is extremely slow so utilizing nursery stock increase the success rate (Table I). Some plants produce seeds infrequently and others only at irregular intervals. Nurseries have the ability to collect seeds during those infrequent seed production years and store them until needed. Propagating plants in nurseries can significantly improve seed use *efficiency* because, in nature, many seeds are eaten by predators and young germinants are lost to drought and other stresses. Plants that propagate vegetatively cannot disperse to new areas very quickly and so planting nursery stock can accelerate this process. Natural plant succession relies on chance whereas planting can assure that the desired species will quickly establish in the desired location and at the proper spacing (Landis et al. 1993).

The most serious disadvantages of using nursery stock include the high initial cost and the lag time between ordering the seedlings and outplanting them (Table 1). However, when computing costs, restoration project managers should consider using the cost per established plant rather than the nursery price. The shorter establishment time with seedlings compared to seed or other plant materials can also make nursery stock more attractive. Nursery culture can take from as little as 6 months to as long as 4 years depending on seed availability and the desired stocktype (Figure 4). Obviously, good planning and communication between the customer and the nursery is an important consideration.

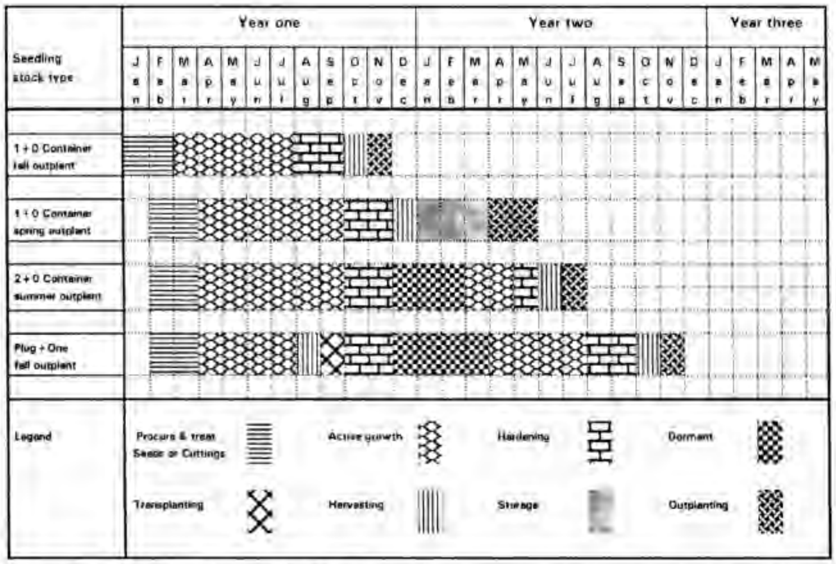

Figure 4 - These crop production schedules illustrate the time required to produce several nursery stock types (from Landis et al. 1999).

Proper source of Seed or vegetative plant material

If nursery stock is the desired target plant material for a restoration project, then the question of genetics must be considered. There are two separate but equally important components: local adaptation and genetic diversity.

Local adaptation

Many native plants can be propagated by seeds but they must be collected on or near the project area. "Seed source" is an idea familiar to all forest nursery managers and reforestation specialists. They know that, because they are adapted to local site conditions, seeds should always be collected within the local "seed zone." Forest and conservation nurseries grow plants by seed zone, which is a three-dimensional geographic area that is relatively similar in climate and soil type. Each zone is stratified by elevation bands that are typically 500 feet (150 m). Seed source affects seedling performance in a couple of ways: growth rate and cold tolerance. In general, seedlings grown from seeds collected from higher latitudes or elevations will grow slower but tend to be more cold hardy during the winter than those grown from seeds from lower elevations or more southern latitudes (Landis et al. 1995). Seed zone research has not been done on many other native plants or for vegetative plant material, but it is only 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 seedlings are to be outplanted.

Genetic diversity

The second genetic consideration when planning for target plant material is to try and capture all the genetic and sexual diversity that exists on the project site. So, when harvesting either seeds or cuttings, collections should be made from as many individual plants as possible to maximize genetic diversity and, in the case of cuttings, to ensure that both male and female plants are equally represented. Guinon (1993) provides an excellent discussion of all factors involved in preserving biodiversity when collecting seeds or cuttings, and suggests a general guideline of 50 to 100 donor plants.

Using a local source for seeds or cuttings and collecting from enough individuals to maintain genetic and sexual diversity should be basic tenets of restoration ecology.

4. Limiting site conditions

The classic ecological "principle of limiting factors" can also be applied to the target plant materials concept. This principle states that, when a process is governed by several factors, its rate is limited by the factor that is closest to the minimum requirement. In the case of a restoration project, target plant material specifications should be developed by identifying which environmental factors will be most limiting to survival and growth on that particular site. For example, on a fire restoration site in New Mexico, shallow soils and grass competition are the most serious factors. On the Kenai peninsula in Alaska, however, cold soil temperatures are limiting to plant survival and growth.

Temperature measurements in the shallow rooting zone do not exceed 50 (10 ˚C) during the summer and research has shown that root growth almost stops completely below this temperature threshold (Landis 1999). By identifying potential limiting factors on the outplanting site, the plant materials that will have the best chance of establishing can be selected.

One potentially limiting outplanting site condition deserves special mention: mycorrhizal fungi. Reforestation sites typically have an adequate complement of mycorrhizal fungi that quickly infect outplanted seedlings whereas many restoration sites do not. For example, severe forest fires or mining operations eliminate all beneficial soil microorganisms including mycorrhizal fungi. Therefore, seedlings destined for these sites should receive inoculation with the appropriate fungal symbiont before outplanting.

Nursery managers must work with seedling customers to identify which environmental factors will be most limiting on each outplanting site. Through these discussions, specification for the best target plant material can be formulated to maximize survival and growth under these specific site conditions.

5. Outplanting window

The timing of the restoration project must also be considered when defining target plant materials. 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 cuttings. As you can see, this component is closely related to the previous one on limiting site conditions. However, the outplanting window also must consider other operational constraints such as access to the site and availability of labor.

The best outplanting window is usually defined by limiting factors and soil moisture and temperature are the usual constraints. In the Pacific Northwest, seedlings are outplanted during the rains of winter or early spring but, in the Southwestern states, the summer monsoon season offers another potential window. In Alaska and other northern latitudes, the outplanting window is later in the summer when soil temperatures are at their peak. In recent years, there has been a renewed interest in fall outplanting. This is primarily due to the availability of properly conditioned container stock. Whereas outplanting projects used to be scheduled when the first fall rains began, foresters are finding that soil temperature may be just as important as soil moisture in determining the outplanting window.

Using information from the seedling customer, nursery managers can develop a crop propagation schedule that will produce the target plant material at the proper time for outplanting. These schedules are unique in that they are constructed in reverse order. Starting at the desired date of delivery, the nursery manager plans backwards to determine how much time will be required to produce seedlings or other plant material with the target specifications (Landis et al. 1999). Crop production schedules for different container seedling stock types are illustrated in Figure 4.

6. Outplanting tools

There is an ideal planting tool for each outplanting site. 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. For example, special planting hoes called hoedads are popular in the steep terrain on the Pacific Northwest but the level terrain in the Southern Coastal Plain allows machine planting, which is much more efficient. Often, planting contractors will choose the implement that gets plants or cuttings into the ground as quickly as possible. This obsession with productivity is understandable but can be counterproductive. For example, the dibble was developed as an easy and quick way to outplant container seedlings. Experience has shown that dibbles work reasonably well on sandy soils but that they create a compacted soil layer in clay soils which inhibits root egress.

New outplanting tools are continually being developed. Specially modified hoedads called "plug hoes" are now available for container stock. The "Expandable Stinger" is a mechanized probe that is used to outplant hardwood cuttings or special "long tube" seedlings in riparian restoration areas (Figure 5). One of the most attractive features of the Expandable Stinger is that the hydraulically powered head can plant seedlings or cuttings into existing rock rip-rap or in dense vegetation such as berry thickets (Steinfeld and Landis 2001). The Waterjet Stinger has recently been developed to outplant nonrooted hardwood cuttings (Hoag et al. 2001). For planning purposes, nursery managers must know which planting tools will be used in advance so that they can develop proper plant material specifications such as seedling root length and volume or cutting length and diameter.

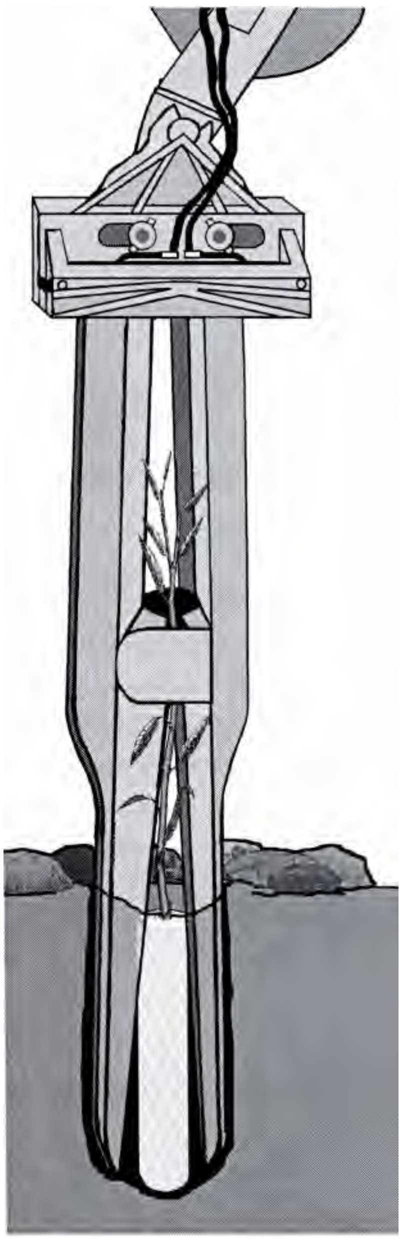

Figure 5 - Target plant materials must consider the outplanting method. This "Expandable Stinger" is hydraulically-powered and can outplant containers or cuttings into difficult locations including rip-rap rock structures along waterways (modified from Steinfeld and Landis 2001).

Improving the Quality of Target Plant Materials

The target plant materials concept is not static but must be continually updated and improved. At the start of the project, the restoration project supervisor and the nursery manager must agree on certain specifications. This prototype target seedling or cutting must be verified by outplanting trials in which survival and growth are monitored for up to five years. The first few months are critical because plant materials that die immediately after outplanting indicate a problem with stock quality. Plants that survive initially but gradually lose vigor indicates poor planting or drought conditions. Therefore, plots must be monitored during and at the end of the first year for initial survival. Subsequent checks after 3 or 5 years will give a good indication of growth potential. This performance information is then used to give valuable feedback to the nursery manager who can fme tune the target specifications for the next crop (Figure 6).

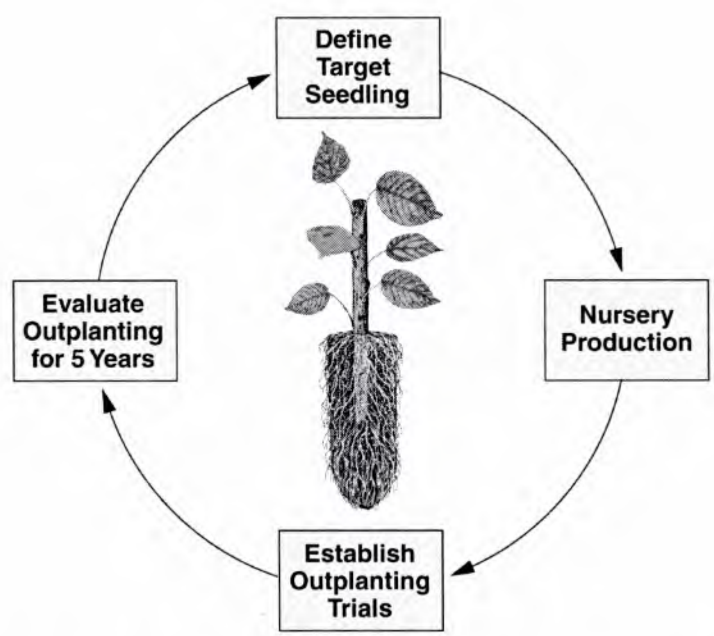

Figure 6 - The target plant materials concept must be continually updated by outplanting performance.

Summary

The target seedling concept was developed to help stimulate and clarify communication between the forest seedling customers and nursery managers. Describing the ideal plant for a particular restoration project and following a series of sequential steps will also be a useful exercise for native plant nurseries and users. Instead of the traditional linear process which begins in the nursery, the target seedling concept is a circular feedback system where information from the outplanting site is used to define and refine the best type of seedling.

References

Baskin, J.M.; Walck, J.L.; Baskin, C.C.; Buchele, D.E. 2000. Ecology and conservation biology of the endangered plant species *Solidago shortii* (Asteraceae). Native Plants Journal I (1): 35-41.

Guinon, M. 1993. Promoting gene conservation through seed and plant procurement. IN: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-22 1, p. 38-46. Landis, T.D., ed. Proceedings, Western Forest Nursery Association.

Hoag, J.C.; Landis, T.D. 2001. Riparian zone restoration: field requirements and nursery opportunities. Native Plants Journal 2(1): 30-35.

Hoag, J.C.; Simonson, B.; Cornforth, B.; St. John, L. 2001. Waterjet stinger: a tool for planting dormant nonrooted cuttings. Native Plants Journal 2(2): 84-89.

Ritchie, G.A. 1984. Assessing seedling quality. IN: Duryea, M.L.; Landis, T.D. eds. Forest Nursery Manual: Production of Bareroot Seedlings. Kluwer Academic Press. The Hague: 243-259.

Landis, T.D. 1999. Seedling Stock Types for Outplanting in Alaska. IN: Stocking Standards and Reforestation Methods for Alaska: Proceedings of the Alaska Reforestation Council; 1999 April 29; Anchorage, AK. Misc. Publication 99-8. Fairbanks, AK: University of Alaska, Agricultural and Forestry Experiment Station: 78-84.

Landis, T.D.; Tinus, R.W.; Barnett, J.P. 1999. Seedling Propagation. Vol. 6, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 166 p.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1994. Nursery Planning, Development, and Management, Vol. 1, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 188p.

Landis, T.D.; Lippitt. L.A.; Evans, J.M. 1993. Biodiversity and ecosystem management: The role of forest and conservation nurseries. IN: Proceedings, Western Forest Nursery Association;1992 Sept. 14-18; Fallen Leaf Lake, CA. Gen Tech. Rep. RM-221. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 1-17.

Newton, G.A. 1993. Assessing the rehabilitation potential of disturbed lands. IN: Proceedings, Western Forest Nursery Association; 1992 Sept. 14-18; Fallen Leaf Lake, CA. Gen Tech. Rep. RM-22 I . Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 27-30.

Pequinot, S.A. 1993. Illinois - an example of how public nurseries can help meet the need for non-traditional plant materials. IN: Proceedings, Western Forest Nursery Association;1992 Sept. 14-18; Fallen Leaf Lake, CA. Gen Tech. Rep. RM-221. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 72-77.

Rose, R.; Campbell, S.J.; Landis, T.D. 1990. Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forest Nursery Associations; 1990 August 13-17; Roseburg, OR. Gen. Tech. Rep. RM-200. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 286 p.

Steinfeld, D.E.; Landis, T.D. 2001. Long Tubes and The Expandable Stinger — A new stocktype and planting method for riparian areas and harsh sites. In: Dumroese, R.K.; Landis, T.D., technical coordinators. Forest and Conservation Nursery Associations. 2001 National Proceedings: http://www.fcnanet.org/proceedings/200 I/steinfeld.pdf