Applying the target plant concept to nursery stock quality

Thomas D. Landis and R. Kasten Dumroese

ABSTRACT

The basic tenet of the target plant concept is that the quality of nursery stock is determined by outplanting performance (survival and growth), rather than characteristics or standards measured at the nursery. This means that there is no all-purpose plant, but that each outplanting project will require different species and stock types. In this paper, we discuss the six basic questions that help define the target plant:

1) What is the project objective?
2) Which species is appropriate and should local or genetically-improved seeds be used?
3) What factors limit survival and growth on the outplanting site?
4) When will the nursery stock be outplanted?
5) How will they be outplanted?
6) What is the ideal stocktype?

The target plant concept is a cyclic, continual process as outplanting site performance is used to update target plant specifications.

WHAT IS NURSERY PLANT QUALITY?

The first attempts to describe an ideal plant always start with morphological characteristics, such as shoot height and stem diameter, which are then converted into grading standards. In the southeastern USA, the classic research of Phil Wakeley resulted in three grades of nursery stock for the major southern pine species. His studies on the ideal pine seedling, however, convinced him that physiological aspects of plant quality were just as important as morphological characteristics (Wakeley 1954). In the last 25 years, research into seedling physiology has revolutionized traditional concepts of reforestation and restoration. This new research helped develop the target plant concept (Rose et al. 1990).

One of the basic tenets of the target plant concept is that quality is determined by survival and growth on the outplanting site. Nursery stock quality depends on how the plants will be used, and the best definition that we have found is 'fitness for purpose' (Ritchie 1984). This means that seedling quality cannot be merely described at the nursery, it can only be proven on the outplanting site. There is no such thing as `all-purpose' nursery stock. A nice looking plant in the nursery will not survive and grow well on all sites. In the western USA, we talk about prescriptions for reforestation sites in which the forester plans what species and stock type should be used. Several states have Tree-to-Growth requirements which stipulate that outplanted nursery stock must not only be alive, but must have grown above the competing vegetation within five years.

DEFINING THE TARGET PLANT

A target plant has been cultured to survive and grow on a specific outplanting site, and can be defined in six sequential steps (Figure 1).

1. Objectives of outplanting project

The way in which nursery stock will be used has a critical influence on the characteristics of the target plant. Typically, reforestation after harvest uses commercially valuable tree species that may have been genetically-improved for fast growth are outplanted with the ultimate objective of producing saw logs or pulp. The target plant for restoration projects can be radically 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. Restoration after wildfire can involve several target plant materials. On commercial forestlands, native grass seeds are sown to stop erosion and then tree seedlings are outplanted to bring the land back to full productivity as soon as possible.

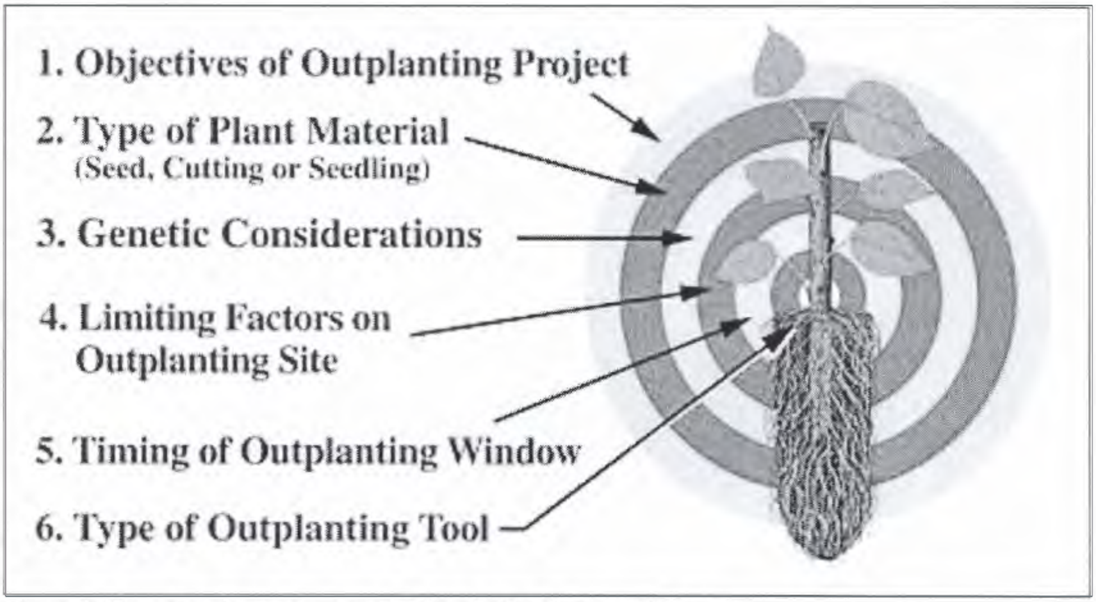

Figure 1: The target plant concept can be described in six sequential steps.

Creating habitat for threatened or endangered plants and animals, such as the Ivory-billed Woodpecker, is yet another project objective. This, the largest North American woodpecker, was thought extinct until last year when a confirmed sighting was made in a remote area of Arkansas. The habitat of the Ivory-billed Woodpecker is swamp and bottomland hardwood forest, most of which has been logged or drained for agriculture. Conservation organizations have initiated tree planting to restore the hardwood forests that these large woodpeckers need for food and shelter.

2. Types of plant materials

Target plant materials include seeds and all the various nursery stock types, including rooted cuttings:

- **Seeds.** Although direct seeding is rarely used in the USA for reforestation, seeds of native grasses, forbs, and shrubs are direct sown for restoration. For example, the Stone nursery in southern Oregon is currently producing over 30 species of native grasses and forbs. Seeds of commercial cultivars have been used in restoration projects for decades, but only recently have reliable supplies of source-identified, locally-adapted native seeds been available.
- **Seedlings and transplants.** Nurseries are currently producing a wide variety of plant stocktypes. In the southeastern USA, the 1+0 seedling, is most common but western nurseries grow a variety of seedling and transplant stocktypes. During the 1960s, forest nurseries began to switch to seedlings because of the high labor cost of transplanting. Precision sowing created ideal seedbed density and root culturing produced seedlings with vigorous root systems and thick stem diameter. In the last 10 to 15 years, however, transplants have returned to favor because of the demand for a large vigorous seedling that can compete with vegetation on outplanting sites and meet 'Free-To-Grow' reforestation requirements (Landis and Scholtes 2003). The newest stocktypes are container-to-bare-root transplants in which small volume container seedlings are transplanted into bare-root beds for another year of growth. Seedlings grown in containers filled with stabilized media can be transplanted even earlier, making possible a one-year container transplant.
- **Rooted cuttings.** Some plants, notably *Salix (L.)* and *Populus (L.)*, are most easily propagated by rooting cuttings. Demand for willow and cottonwood species has become more common in the last decade because of an increased interest in riparian restoration.

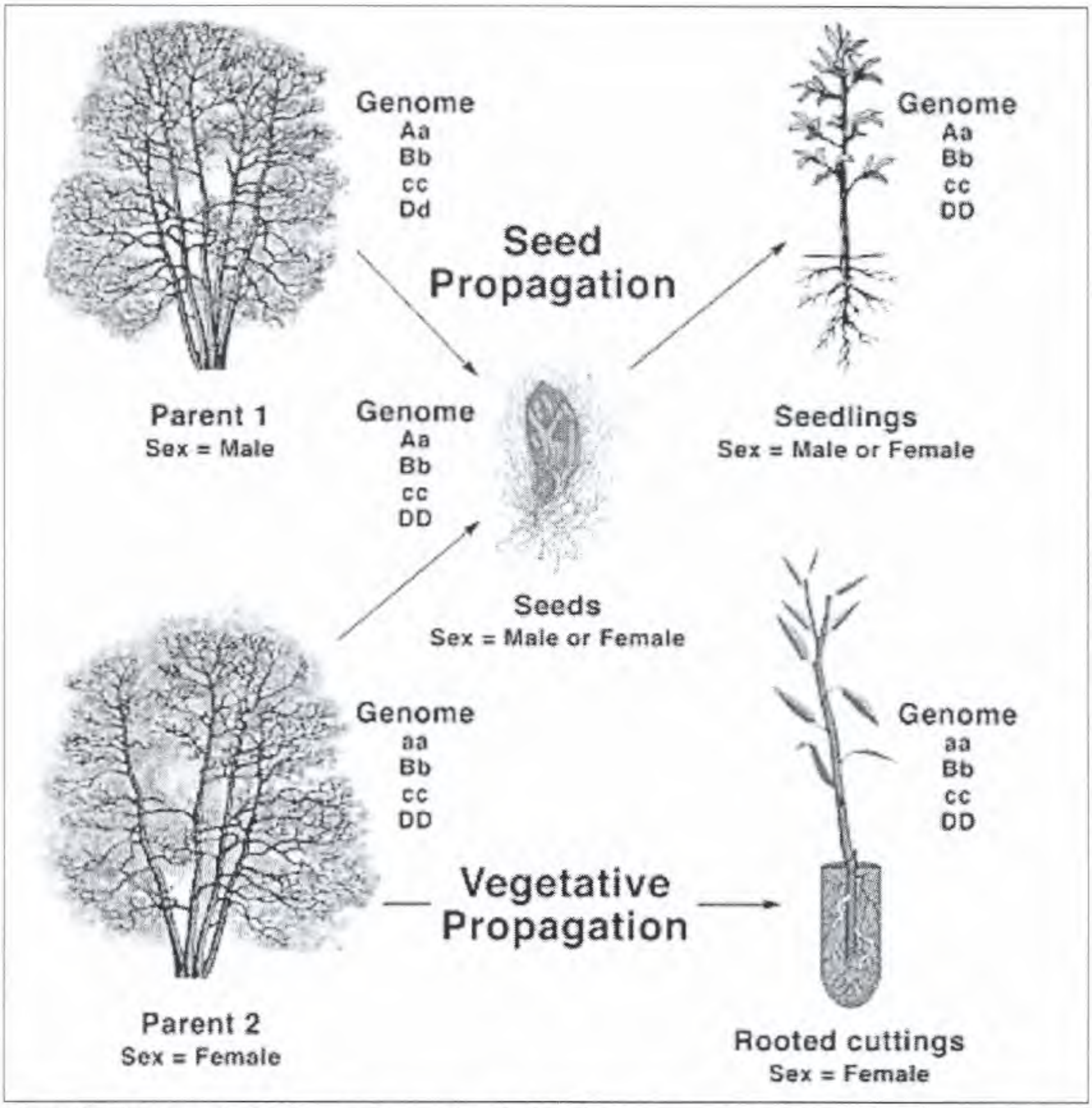

Figure 2: The target plant concept must consider whether plants were propagated by seeds or by cuttings because the choice will affect both genetic and sexual diversity.

There are drawbacks to vegetative propagation, however. Sexual propagation results in a mixture of genetic characteristics so that the offspring contain both male and female plants. On the other hand, asexual propagation methods produce exact clones of the mother plant. This is of particular concern with dioecious plants, such as willows and cottonwoods, because all the progeny produced by vegetative propagation will have the same sex as their parent (Figure 2) (Landis et al. 2001).

3. Genetic considerations

The third component of the target plant concept is concerned with how well outplanted nursery stock will be adapted to the local environment. Selection of the proper species is the primary consideration. Ecologically dominant or commercially valuable trees are routinely chosen for traditional reforestation, although species with unique characteristics are sometimes preferred. In the mountains of the northwestern USA, for example, lodgepole pine (*Pinus contorta* var. *contort* Engelm.) is prescribed for low areas known as frost pockets because of this species's extreme cold tolerance.

Although commercial forest plantations have traditionally been monocultures of the most valuable species, planting a mix of species is now being reconsidered. Multiple species plantings improve biodiversity and create habitat but can also have economic benefits. A recent economic analysis of a mixed plantation of Norway spruce *(Picea abies* L.) and beech *(Fagus sylvatica* L.) concluded that mixed outplantings are not only ecologically beneficial but can also be economically justified (Knoke et al. 2005).

Once the proper species have been selected, the next consideration is genetic adaptation. Seed source and seed zones arc familiar terms to foresters. They know that plant species vary throughout their geographic range because they are adapted to local site conditions. Forest nurseries in the western USA grow plants by seed zone, which is a three-dimensional geographic area that is relatively similar in climate and soil type (Figure 3). On the other hand, local adaptation is not always considered in ornamental nurseries. For example, both native plant nurseries and ornamental nurseries grow Douglas fir *[Pseudotsuga nienziesii* (Mirb. Franco)] seedlings but the former distinguish between ecotypes (e.g. variety glauca) and ornamental nurseries offer different cultivars (e.g. `Camellix Weeping') (Landis 2001). The same principles apply to plants that must be propagated vegetatively. Cuttings must be collected from near the outplanting site to make sure that they arc properly adapted.

Seed source affects outplanting performance in a couple of ways: growth rate and cold tolerance. In general, plants 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 (St Clair and Johnson 2003). Therefore, it is prudent to always specify seeds or cuttings from the same geographic zone and elevation in which the seedlings are to be outplanted.

4. Limiting factors on the outplanting site

The fourth aspect of the target plant concept concerns the ecological 'principle of limiting factors'. The specifications of the target plant should be developed by identifying which environmental factors will be most limiting to survival and growth on that particular site (Figure 4). Moisture availability is the most common limiting factor but at higher elevations and latitudes, cold soils may be more of a restriction. On these sites, temperature measurements in the shallow rooting zone may not exceed 50°F (10°C) during the summer and

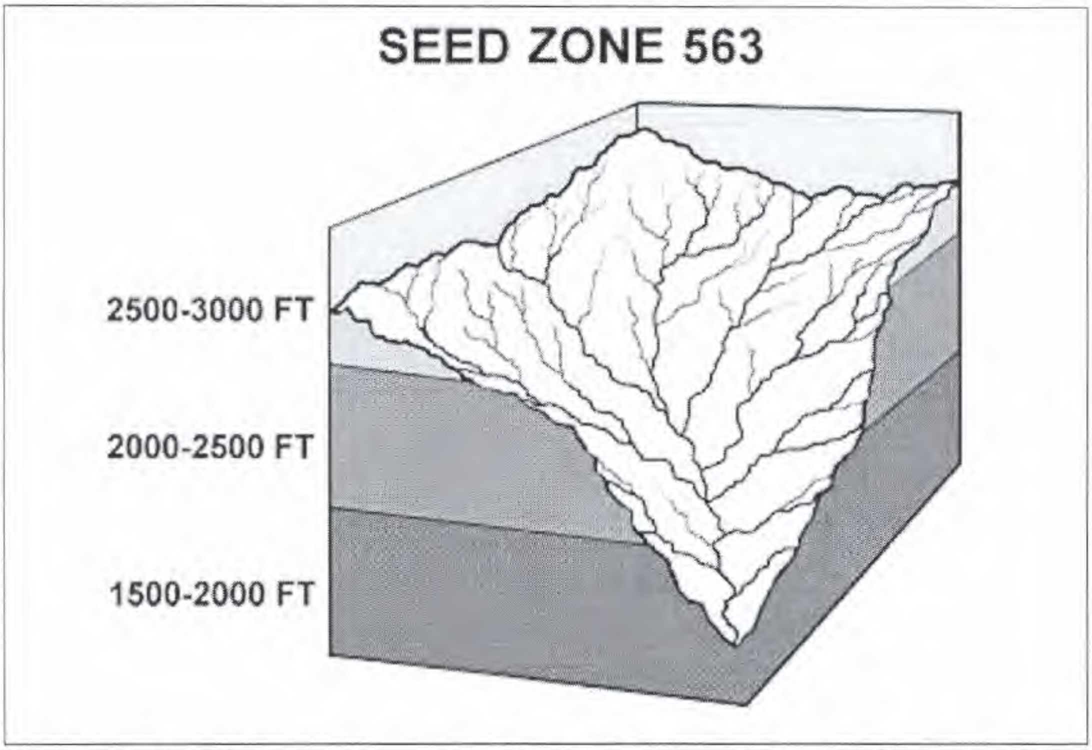

Figure 3: A seed zone is a geographic area that is relatively similar enough in climate and soil type and is described by a numerical code. In the mountainous western USA, seed zones are also stratified vertically by elevation bands.

research has shown that root growth almost stops completely below this temperature threshold. A reasonable target seedling for these sites would be grown in a relatively short container to take advantage of warm surface soils (Landis 1999). For high elevation reforestation sites in British Columbia, CANADA, Faliszewski (1998) concluded that the target seedling should be short with a compact root system.

One outplanting site condition deserves special mention — mycorrhizal fungi. Reforestation sites typically have an adequate complement of mycorrhizal fungi that quickly infect outplanted plants, whereas most afforestation and restoration sites do not. For example, severe forest fires or mining operations eliminate all soil micro-organisms including mycorrhizal fungi. Therefore, plants destined for these sites should receive inoculation with the appropriate fungal symbiont before outplanting. The timing of the inoculation must also be considered because many mycorrhizal fungi will not survive in the high nutrient environment of the nursery.

5. Timing of the outplanting window

The timing of the outplanting project is the fifth aspect of the target plant concept that should be considered. The outplanting window is the period of time in which environmental conditions on the outplanting site are most favorable for survival and growth. As mentioned in the previous section, soil moisture and temperature are the usual constraints. In the Pacific Northwest USA, plants are outplanted during the rains of winter or early spring: in the mountains of Mexico, however, outplanting is done during the summer rainy season. Soil temperature rather than moisture is the consideration at high elevations or latitudes, so container stock is outplanted in mid-summer or early autumn.

Container plants are uniquely suited to mid-summer and autumn outplanting because they can be artificially conditioned to withstand handling stresses (Figure 5). For example, autumn outplanting with containers on high elevation sites in northern California, USA has shown a 50 to 100% increase in stem volume compared to spring planting (Fredrickson 2003). Summer outplanting is a relatively new

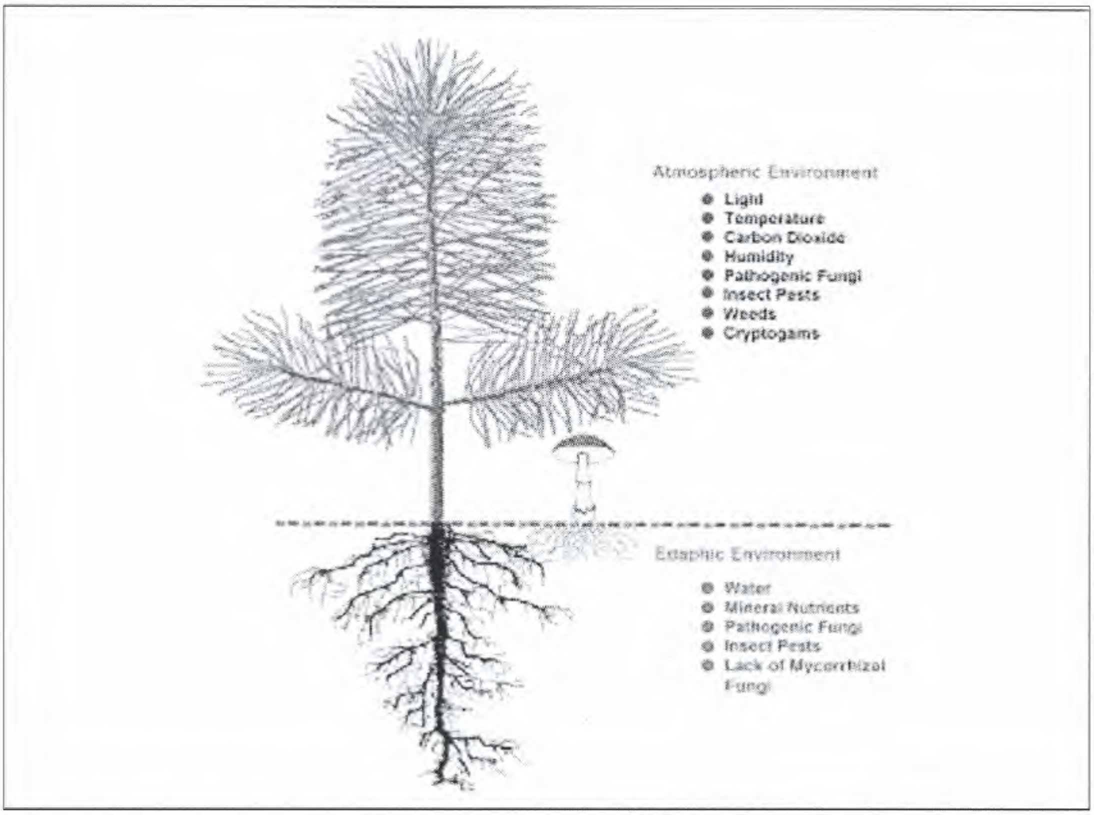

Figure 4: Defining the limiting factors on each project site is crucial to the target seedling concept.

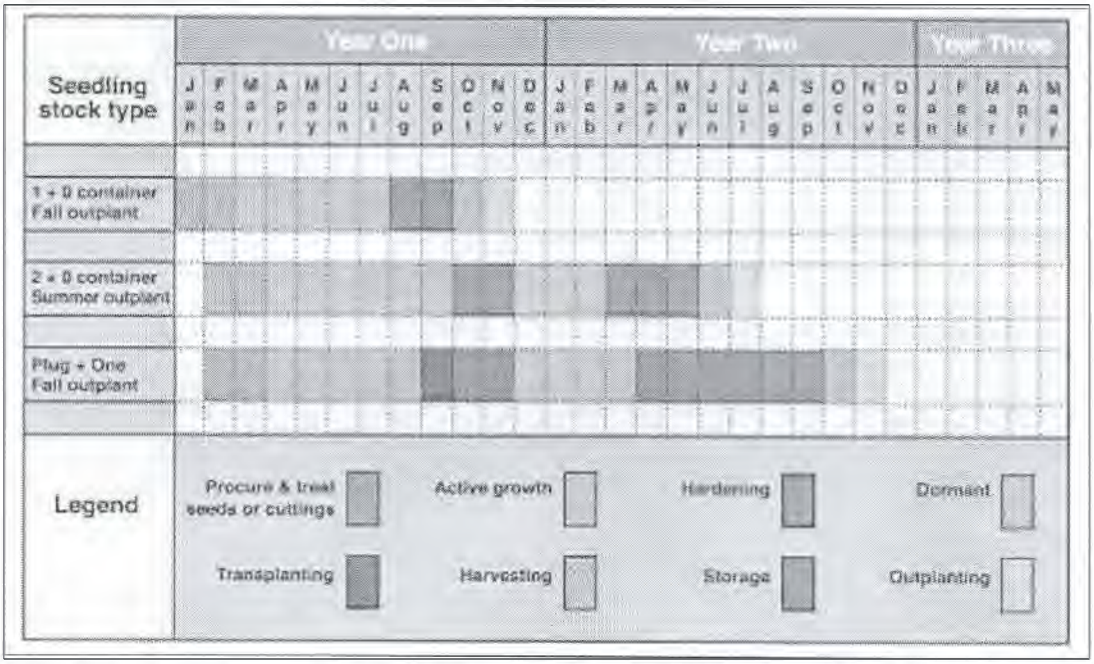

Figure 5: Summer and autumn outplanting are now possible for high elevation or high latitude sites, but the container stock is produced with special nursery production schedules that incorporate special conditioning.

practice that developed in the boreal regions of Canada (Revel et al. 1990) and has since found some application at high elevation sites in the Rocky Mountains of the USA (Page-Dumroese and Dumroese, unpublished data). Target plant characteristics are similar for both summer and autumn outplanting: hardened container stock with minimal handling and storage.

6. Outplanting tools and technique

A wide variety of hand outplanting tools have been used successfully (Lowman 1999), and therefore tools and outplanting techniques must be considered in the target seedling 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 perform well under all site conditions. Often, planters will choose the implement that gets plants 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, in clay soils, they create a compacted soil layer that inhibits root egress.

Several machine planters are commercially available, but this equipment imposes unique restrictions because the target seedling must conform to the size and shape of the handling equipment. With tractor-drawn continuous furrow planting machines, nursery stock must have stem diameters that fit the holding clips on the planting wheel, and their root systems must not be longer than the depth of the furrow. Self-propelled spot planting machines were designed for container stock. For example, the Swedish Bracke planter has interchangeable magazines that will handle container plants with total heights of 50, 60, 70 mm (Stirling 2000). So, where mechanical planting is used, the target plant is more defined by the type of outplanting tool rather than any of the other factors.

The type of outplanting tool must be given special consideration when working with volunteers or other inexperienced planters. Many of these people do not have the skill or strength necessary to properly place plants on wildland sites. One option is to have a professional create planting holes with a machine auger and let the volunteers insert plants and tamp them into place. This technique has several benefits: the professional chooses the proper planting spot, creates the desired pattern, and makes certain that the planting hole is large and deep enough to avoid `j-roots'.

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 (Figure 6A). The same technique is used for Christmas tree plantations where tree growth and form are the main concerns. Where ecological restoration is the objective, however, outplanting plants randomly (Figure 6B) or in random groups (Figure 6C) is more representative of natural vegetation patterns.

FIELD TESTING THE TARGET PLANT

One of the unique aspects of the target plant concept is that it is a collaboration between nursery managers and their customers. At the start of any planting project, the customer and the nursery manager must 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 five years. The first few months are critical because nursery plants 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 three or five years will give a good indication of plant growth potential. 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

As an example for the western USA, the Oregon State University Nursery Technology Cooperative is conducting outplanting trials of one-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 fire in the Coast Range. In terms of survival, the Styroblock® container performed much better than the transplants at Timber Rock, whereas there was little difference on the wetter Biscuit site (Table 1). The container stocktype also grew much better at both sites, but especially so at the Timbered

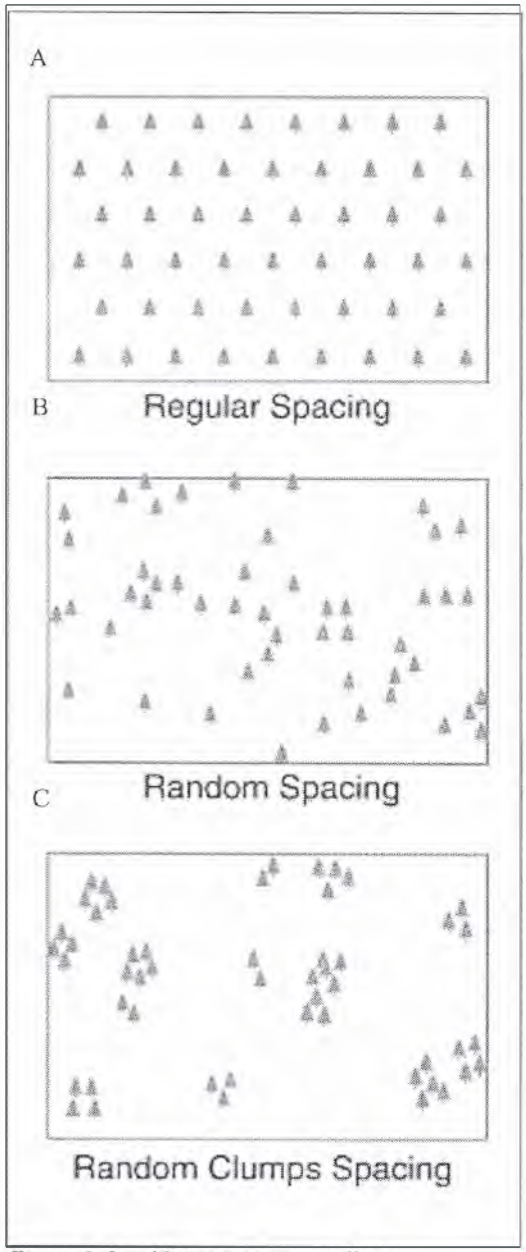

Figure 6: In addition to target seedling specifications, the objectives of the outplanting project also affect planting patterns. If the objective is rapid growth or Christmas trees, then the plants can be regularly-spaced (A). Most restoration projects want to avoid the 'cornfield look', however, and so plants are spaced in a more random pattern that would mimic natural conditions (B). The most natural outplanting look uses the random clumped pattern where different species are planted in groups (C).

Table 1: Outplanting performance of Douglas fir stock types on different outplanting sites after one growing season (Nursery Technology Cooperative 2005).

Stocktype	Survival (%)	Height Growth (cm)	Stem Diameter Growth (mm)
Timbered Rock Fire - Oregon Cascade Mountains			
1+1 Bare-root Transplant	14 c *	4.2 b	- 0.6 b
Q-Plug Container Transplant	39 b	2.6 b	- 0.3 b
Stryoblock® Container - 246 cc	87 a	12.0 a	0.8 a
Biscuit Fire - Oregon Coastal Mountains			
1+1 Bare-root Transplant	98 a	4.6 b	0.5 b
Q-Plug Container Transplant	98 a	7.0 a	0.5 b
Stryoblock® Container - 246 cc	99 a	7.5 a	1.1 a

* Within each site, means followed by the same letter are statistically different at the $p \leq 0.05$ level

Rock site 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.

CONCLUSIONS

Propagation of plants for afforestation, reforestation, or restoration is a cyclic operation. Similarly, the process of deciding upon, and growing, the best plants for a particular site should be a cyclic process between the land manager and the nursery. The target plant concept is a comprehensive, yet adjustable, system for producing the best nursery stock for any project. An ideal nursery plant, suitable for all purposes, does not exist. Instead, the ultimate use of the plants controls all aspects of the nursery programme. Nursery managers should grow the type of stock that is appropriate, rather than land managers having to use whatever the nursery produces. Key to this process is good communication. Nursery stock, grown using the target plant concept, are the result of field observations and the ultimate test of quality is outplanting performance. Thus, the target plant concept insures that the best possible quality stock will be outplanted and that subsequent survival and growth will be used for further improvements.

REFERENCES

B.C. Ministry of Forests. 1998. *Provincial seedling stock type selection and ordering guidelines.* Victoria, BC: Ministry of Forests, Forestry Division. 71 p.

Faliszewski, M. 1998. *Stock type selection for high elevation (ESSF) planting.* Forest Nursery Association of British Columbia meetings, proceedings, 1995, 1996, 1997:152.

Fredrickson, E. 2003. *Fall planting in Northern California.* In: Riley L.E., Dumroese R.K., Landis T.D. (technical coordinators). National Proceedings:Forest and Conservation Nursery Associations-2002. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-28: 159-161.

Knoke, T., Stimm, B., Ammer, C. and Moog, M. 2005. Mixed forests reconsidered: A forest economics contribution on an ecological concept. *Forest Ecology and Management* 213: 102-116.

Landis, T.D., Dreesen, D.R. and Dumroese, R.K. 2003. Sex and the single Salix: considerations for riparian restoration. *Native Plants Journal* 4(2):1 10-117.

Landis, T.D. 2001. *The target seedling concept: the first step in growing or ordering native plants.* In: Haase, D.L. and Rose, R. (eds). Native plant propagation and restoration strategies, proceedings of the conference. Corvallis, OR: Oregon State University, Nursery Technology Cooperative and Western Forestry and Conservation Association: 71-79.

Landis, T.D. 1999. *Seedling stock types for outplanting in Alaska.* In: Stocking standards and reforestation methods for Alaska. Agricultural and Forestry Experiment Station, Misc. Publication 99-8. Fairbanks, AK: University of Alaska Fairbanks: 78-84.

Landis, T.D. and Scholtes, J.R. 2003. *A history of transplanting.* In: Riley L.E., Dumroese R.K. and Landis, T.D. (technical coordinators). National Proceedings: Forest and Conservation Nursery Associations - 2002. Ogden, UT: