Target Seedling Symposium

Chapter 1
The Target Seedling Concept

Robin Rose, Project Leader, Nursery Technology Cooperative, Department of Forest Science, Oregon State University, Corvallis, Oregon

William C. Carlson, Tree Physiologist, Weyerhaeuser Company, Southern Forestry Research Department, Hot Springs, Arkansas

Paul Morgan, Nursery Manager, D. L. Phipps Nursery, Oregon Department of Forestry, Elkton, Oregon

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ABSTRACT

The target seedling concept means to target specific physiological and morphological seedling characteristics that can be quantitatively linked with reforestation success. For decades foresters have relied on the stocktype designation, height, and caliper to grade seedlings. Nursery technology has advanced to the point where it is possible to achieve greater predictability in how seedlings will perform after outplanting. This paper highlights the concept of target seedlings and their importance to reforestation.

1.1 Introduction

A target seedling embodies those structural and physiological traits that can be quantitatively linked to successful reforestation. For many years reforestation specialists have searched for the characteristics that increase seedling survival and growth after outplanting. Only within the past three decades have they realized that height and diameter are not the only seedling traits affecting field performance. The target seedling concept is based on the premise that numerous seedling traits must work together to produce the desired field response. This paper highlights the concept of target seedlings and their importance to reforestation.

1.2 Development of the Concept

Technological advances in crop management and increased knowledge of seedling establishment have improved nursery crop quality. Now reforestation specialists realize that cultural practices in the nursery affect how well seedlings perform in the field. For example, undercutting and wrenching can have the dramatic effect of increasing root system size, which has long been linked to improved survival. Top clipping can improve field survival of excessively tall seedlings by lowering the shoot/root ratio. Altering fertilizer and irrigation schedules to encourage bud set and induce dormancy can greatly improve frost hardiness in the fall, winter storability, and stress resistance during and following planting. Currently, many nursery personnel emphasize culling standards strongly weighted toward height and diameter, because these are easily judged in the packing shed and are broadly correlated with other factors of seedling quality. Attention is often on maximizing the number of seedlings that can be shipped because they exceed the culling standards rather than on maximizing the number of seedlings that will survive and grow well.

Target seedlings go a step beyond. The standard for target seedlings is achieved by supplementing culling standards with information on such physiological and morphological characteristics as root volume, plant moisture stress, and frost hardiness. Other targeted traits include the presence of secondary needles and a firm bud, as well as presence of the proper nutrient levels and dormancy characteristics. Knowledge of these traits is used to improve the cultural techniques that tailor seedlings in the nursery.

Several years ago, Weyerhaeuser Company defined a target seedling for its southern pine operations by asking regeneration foresters to observe the morphology of the seedlings that consistently survived and grew well. Over a two-year period, foresters from each operating region described their target seedlings after June estimates of survival and at the end of the first year after planting. The results are shown in Figure 1.1. Weyerhaeuser has since

TARGET SEEDLING: LOBLOLLY PINE

Height 20-25 cm
Diameter >4mm
Mostly secondary needles
A single dominant stem possessing a well-developed terminal bud with resinous bud scales
A minimum of six first-order lateral roots, fiberous in character and mycorrhizal
Root volume = >3.5 ml
High root growth potential

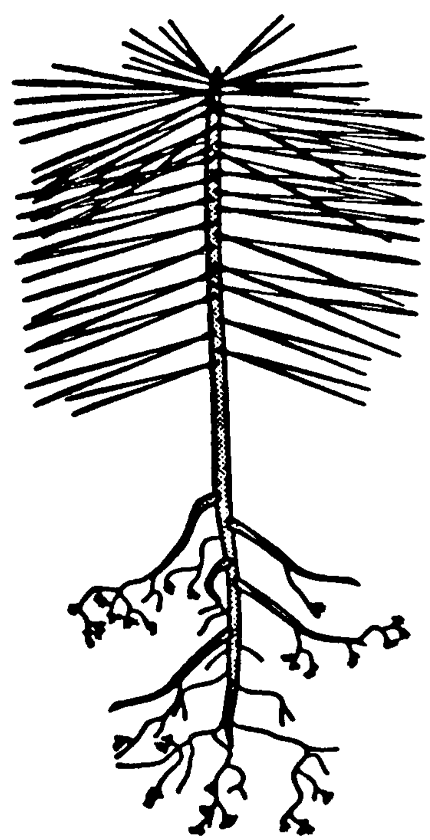

Figure 1.1—*Weyerhaeuser Company's loblolly pine target seedling.*

used this seedling not only as the goal for its cultural practices in the nursery, but also as a standard for rating its nursery crops. There is, of course, no such thing as a universal target seedling; adoption of this concept can, however, lead to crops of higher quality, especially if targets are established both by talking to users and by conducting physiological tests to determine the effects of cultural practices.

How, then, are cultural practices in the nursery affected by knowledge of target seedling morphology? The morphological traits that describe seedlings have normal population distributions (Figure 1 .2). Cultural practices shift the distributions to the right or the left of the mean. Some of the target morphological traits are specified as minimums, some as maximums, and some as ranges. These limits appear at different places in the population distributions, depending on management practices. Research can be conducted to develop cultural practices that shift the population distribution in the desired direction. For instance, at the cost of losing a well-developed bud, top clipping can shift the shoot/root ratios of individual seedlings downward, thus moving a poorly managed nursery crop's unfavorable 4:1 ratio to a favorable target range below 2:1. If, however, customers differ in the desired seedling morphologies, then separate areas of the nursery should be managed differently. Similarly, genetic families of seedlings often differ in their responses to cultural practices and should be grouped accordingly in the nursery's management areas. Mixed family seedlots are difficult to culture because they usually contain families with different cultural responses.

Cultural practices are thus governed by the target traits decided upon. Certain traits have proved more satisfactory than others as indicators of seedling quality.

1.3 Seedling Traits to Consider

It should be recalled that a key element in the target seedling concept is that many seedling traits operate together to produce the desired field response. Thus, each of these traits affects many others.

1.3.1 Height

The greater the height of a seedling, the greater the leaf area available for photosynthesis and transpiration and the greater the seedling's weight and bulk. Greater weight and bulk, of course, decrease the number of seedlings that can be carried by an individual during planting. Height affects the shoot/root ratio of seedlings. The limiting factor in setting a practical height is actually the amount of root that can be planted properly.

1.3.2 Diameter

Diameter is closely related to seedling vigor, partly because average diameter of a seedling population at any one time is correlated with the average size of its root system. Furthermore, stems with larger diameters tend to have larger buds (unless they have been top-pruned). Such buds contain larger numbers of pre-formed leaf primordia that will elongate to become the first flush of growth after planting. Seedlings with larger diameters also have larger xylem cross-sectional areas for water transport, although during establishment the size of the root system is the limiting factor for this process (Carlson 1986).

1.3.3 Size of root system

In addition to increasing the potential for water uptake, larger root systems within a single genetic source also have a higher root growth potential. The size of a root system can also affect the rate of transpiration and gas exchange. Small-rooted seedlings are water-stressed because not enough water is absorbed by the roots to balance transpiration losses from the needles. If this condition is chronic, then currently available photosynthate can become the limiting factor for root growth. High root volume has been shown to improve growth after planting (Rose et al., in review).

1.3.4 Cold hardiness

Nursery managers have long known that a seedling's dormancy status and cold hardiness affect when it should be lifted and handled (Lavender 1984). Changes in such phenological traits as date of bud set, bud size, needle color, and degree of root suberization are now being used to

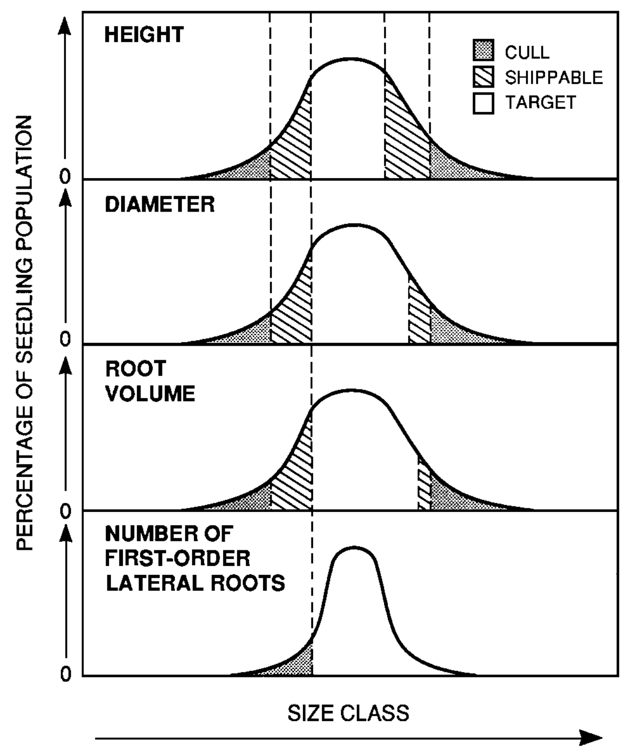

Figure 1 .2—*Normal population distributions for several morphological traits of tree seedlings.*

estimate the dormancy status of seedlings prior to lifting them in the fall and spring for transplanting or outplanting. Unlike morphological measures, however, dormancy and cold hardiness have not often been considered as operationally useful target characteristics.

By putting seedlings through a pre-set freezing cycle, one can quantify their LT_{50}—the lethal temperature at which 50 percent of them sustain some sort of bud, cambium, or needle damage. It is thus possible to determine at any particular time the cold hardiness of seedlings and, therefore, when to lift and store them. The targeted LT_{50} depends on the intended use of the seedlings and the species. A low LT_{50} is less important for seedlings about to be transplanted in the fall than for those going into long-term freezer storage in late winter.

1.3.5 Mitotic index

Mitotic Index or MI (number of dividing cells/total number of cells) is used by researchers to investigate bud dormancy (Carlson et al. 1980). It has also been used successfully on roots (Dunsworth and Kumi 1982). A squash mount of a bud or root observed through a microscope at 400X magnification allows the number of dividing cells to be counted. MI tends to decrease rapidly in the fall in some species. In Douglas-fir, it remains at zero from early December until mid-March—the period when transplanting is most successful. It has potential as a target characteristic, although first the effects of cultural practices on MI, and of various MI values on seedling quality, must be determined.

1.3.6 Days to bud break

Terminal and lateral buds of seedlings are now viewed as potentially useful indicators of whether a seedling has had its chilling requirement met. Seedlings require chilling to break dormancy in the spring. The number of days before terminal and lateral buds break is being used successfully to target the best time to lift seedlings (Ritchie 1983).

1.3.7 Plant moisture stress

Plant moisture stress is used as a target characteristic. As moisture stress in a seedling increases, there is a corresponding degradation of the photosynthesis mechanism and an impairment of future growth. Most nurseries try to lift their seedlings when the water potential of stems, branches, or needles is below -10 bars. It is equally important to plant seedlings when stress levels are low.

1.4 Setting Up a Target System

Making the concept of a target seedling work requires considerable attention to detail from seed selection and sowing all the way through to planting. To achieve the desired end product it is a matter of applying cultural treatments to the seedlings and recording the responses. All of this is done in the context of the growing cycle of the seedlings.

A workable system that allows for the keeping of detailed records year to year requires effort and expense to set up and maintain, but this is outweighed by the rewards that accrue. The example below comes from a large white spruce containerized nursery and shows how the necessary information to track seedling growth relative to cultural practices can be recorded and used. Only a small portion of the information is presented here.

Table 1 .1 shows the Growth Component Sheets for the month of March, which covers growing weeks 6, 7, 8, and 9. The management practice for each growth component (e.g., growth stage of seedlings, light, temperature) are described. Separate detail sheets are also used for the fertilizer schedule and growth measurements.

Examples of the Detail Sheets are shown in Tables 1.2 and 1.3 for the month of April and cover weeks 10, 11, 12, and 13. The Fertilizer Schedule contains the information on the fertilizer formulations, target fertilizer solution versus actual, and target versus actual values for needle nutrients. The Growth Measurements sheet compares target versus actual values for 1 8 physiological and morphological parameters.

Figures 1.3 and 1.4 show how effectively all of this information can be integrated and used operationally with regard to height and plant dry weight. Ultimately, all measurable parameters can be tracked and, when looked at together, give a total picture of the target seedling. In this kind of system it is possible to seed the cultural practice work in relation to the growth of the seedlings. if, at any time, more information is needed, it is a simple process to add another growth component to track and, if necessary, add a new detail sheet for it. This system lends itself readily to computer spreadsheets and data analyses.

1.5 Who Sets the Target?

Different targets are established for different reasons—as a public service, for profit through the sale of seedlings, or for profit at final harvest. Various cultural practices are applied to achieve the desired target. As these practices can result in a wide range of seedling morphologies and physiological conditions, nurseries must decide what practices to employ to achieve their goal. Ideally, no matter what goal, every nursery should be growing seedlings which survive and grow well after outplanting. The proper place to rate the quality of cultured seedlings is in the forest plantation. High-quality seedlings survive well and become established rapidly enough to show substantial height growth the year of planting, and are thus enabled to express their full genetic potential. Definition of the target seedling should reside with the person who sets the

Table 1.1—*Example of growing regime for white spruce containerized seedlings showing growth component's criteria. Shows transition from juvenile development stage to acceleration growing period.*

[GRTHCOMP.1] **GROWTH COMPONENTS**	Timing Week Number 1 Weeks for Seeding (6)	2 (7)	3 (8)	4 (9)
	JUVENILE DEVELOPMENT (Juvenile Stage Ends at Approx. 42 Days)	**ACCELERATION GROWING PERIOD** (Acceleration Stage Starts at Approx. 43 days)		
GROWTH STAGE Soil Medium	pH 5.0 to 5.5 Elec. Conductivity: 0 to 1200 µS/cm = Low 1201 to 2500 µS/cm = Normal 2501 to 3000 µS/cm = High 3001 to 4000 µS/cm = Excessive 4001 = Lethal - pH & EC levels are monitored starting 8th week and every week after until Sept.	- This phase aims at pushing seedling height, root collar diameter, root development and initiate stem lignification - Rapid shoot elongation - Few if any of the seedling will have a visible terminal bud - This growth stage ends when a acceptable percentage of seedling reach 80% of the desired shoot target		
GROWTH MEASUREMENTS (See Detail Sheet GM#)	Weekly growth measurements are started 8 weeks after sowing until Bud Set and biweekly thereafter plotted against previous growth curves			
DAY TEMPERATURE Optimum Min. -> Max.		21° C 17 ° to 25° C		
NIGHT TEMPERATURE Optimum Min. -> Max.		16°C 12° to 20° C		
ENVIRONMENTAL CONTROLS		N/A		
RELATIVE HUMIDITY Optimum Min. -> Max.		60% 50% to 70%		
LIGHT Natural Supplemental		Outside Conditions For photoperiod extension (as in juvenile stage): - Monitor light intensities in greenhouse to ensure 400 lux min. is being maintained - This lighting allows the seedling to take full advantage of normal daylight. Extends growing hours by approx. 2 hrs.		
FERTILIZER SCHEDULE (See Detail Sheet)		Again depending on growth of seedlings would in most cases occur around 7-8th wk N P K Iron Chelate 125 60 159 5.5 ppm (1 appl/week for 6-7 wks)		

[March] - II

GRTHCOMP.2] **GROWTH COMPONENTS**	Timing Week Number 1 Weeks for Seeding (6)	2 (7)	3 (8)	4 (9)
	JUVENILE DEVELOPMENT (Juvenile Stage Ends at Approx. 42 Days)	**ACCELERATION GROWING PERIOD** (Acceleration Stage Starts at Approx. 43 days)		
IRRIGATION pH Electrical Conductivity	- Monitor and record irrigation applied in time and amounts	As before in Juvenile Stage Plus: - General watering (approx. 1/2 hr) 24-48 hrs prior to scheduled fertilizer application - Flush out trays for 1 to 1 1/2 hrs every 3 wks to purge any salt buildup (flush thoroughly)		
CO_2 LEVELS		CO_2 production reduced to 6 hrs (0600 to 1200 hrs) Same ppm as juvenile		
INSECT AND DISEASE CONTROLS		Continue monitoring		
PESTICIDE APPLICATION		One Benlate preventative soil drench @ _____________		
RECORD KEEPING	- Irrigation applied in (mL) greenhouses	- Monitor crop daily - Keep records updated - fertilizer – growth measurements - irrigation – nutrient analysis - pH & EC – temps and RH - photoperiod - Routine maintenance and operational greenhouse checks - Checks on calibration of all greenhouse equipment, i.e., lights on timer are working		
OPERATIONS				
Properly for photoperiod				

Table 1.2—*Example of fertilizer schedule detail sheet showing target and actual amounts found in various solutions and needles.*

[FERTSCH. 3]

FERTILIZER SCHEDULE

Detail Sheet FS #

[April]-III

		FORMULATION & TYPE (Percentage %)			RAW WATER ppm		STOCK SOLUTION ppm		GH FERTIGATION ppm		NEEDLE NUTRIENTS % and ppm	
					Range	Actual	Target	Actual	Target	Actual	Target	Actual
NITROGEN	N	20	10	0	< 6	1.79	25,000	19,820.50	125	148.85	1.50/2.50%	2.57%
Nitrate	N_3											
Ammonium	N_{H4}											
PHOSPHORUS	P	0	52	0	< 6	0.52	12,000	9,670.00	60	52.40	0.18/0.32%	0.35%
Phosphate	H_2PO_4											
POTASSIUM	K	25	10	62	< 6	3.20	31,800	27,650.00	159	153.50	0.45/0.80%	1.30%
CALCIUM	Ca				< 121	43.55		52.00		52.65	0.10/0.20%	0.40%
MAGNESIUM	Mg				< 26	14.40		49.05		15.90	0.15/0.40%	0.16%
SULFUR	S				< 201	45.10		2,175.00		205.00		
Sulfate	SO_4^2											
IRON	Fe	Chelated Iron			< 6	0.08	1,100	1,230.00	5.5	6.85	60/200 ppm	
ZINC	Zn				< 0.6	0.12		23.00		0.64	30/150 ppm	
COPPER	Cu				< 0.3	1.08		12.20		0.31	4/ 20 ppm	
BORON	B				< 0.6	0.01		23.40		0.09	20/100 ppm	
MOLYBDEMUM	Mo				< 0.3	--		4.56		0.02	0.25/5.00 ppm	
OTHER: CHLORINE	Cl				< 101	--		11,400.00		60.50	--	
MANGANESE	Mn				< 1.0	0.01		33.85		0.33	100/250 ppm	
PH					3.0-8.0 (0 pt. 5.5)	6.72						
ELECTRICAL CONDUCTIVITY					< 750 µS	385 µS						

APPLICATION PROCEDURES AND TIMING

20-0-25 = 4.5 kg
10-52- 10 = 24 kg
0-0-62 = 0.6 kg
Chelated Iron = 0.5 kg
Mixed in 10 gals

Table 1.3 –*Example of growth measurements detail sheet showing target and actual values for the seedlings.*

[GRTHMEAS.4]

GROWTH MEASUREMENTS

[April]

Week Number / Weeks from Seeding	1 (10)		2 (11)		3 (12)		4 (13)	
	TARGET	ACTUAL (1989)	TARGET	ACTUAL (1989)	TARGET	ACTUAL (1989)	TARGET	ACTUAL (1989)
GERMINATION								
Seedling Emerged								
Cavities Filled & %								
HEIGHT (cm)	5.00	5.17	6.50	6.50	7.50	7.38	9.00	8.86
ROOT COLLAR DIAMETER (mm)	0.95	0.77	1.25	0.87	1.45	1.19	1.55	1.22
Sturdiness Quotient	(5.26)	(6.71)	(7.47)	(7.47)	(5.17)	(6.20)	(5.81)	(7.26)
ROOT INTENSITY (mg/cc)	0.46	0.23	0.62	0.30	0.77	0.42	0.92	0.59
ROOT VOLUME (cc)	--	--	--	--	--	--	--	--
SHOOT DRY WEIGHT (mg)	125.00	74.19	175.00	103.04	225.00	146.91	275.00	196.80
ROOT DRY WEIGHT (mg)	30	15.24	40.00	19.60	50.00	27.57	60.00	38.31
PLANT DRY WEIGHT (mg)	155.00	89.43	215.00	122.64	275.00	174.48	335.00	235.11
Shoot/Root Ratio	(4.17)	(4.87)	(4.38)	(5.26)	(4.50)	(5.33)	(4.58)	(5.14)
TERMINAL BUD DEVELOPMENT								
Bud Elongating %								
Bud Initiation %								
Bud Set %								
Bud Burst %								
Bud Reflush %								
(Lammas Growth)								
P.M.S. (bars)								
(Drought Stressing)								
OPTIONAL								
Frost Hardiness Tests								
Root Growth Capacity								
Days to Budbreak								
(Freezer stored seedlings only)								

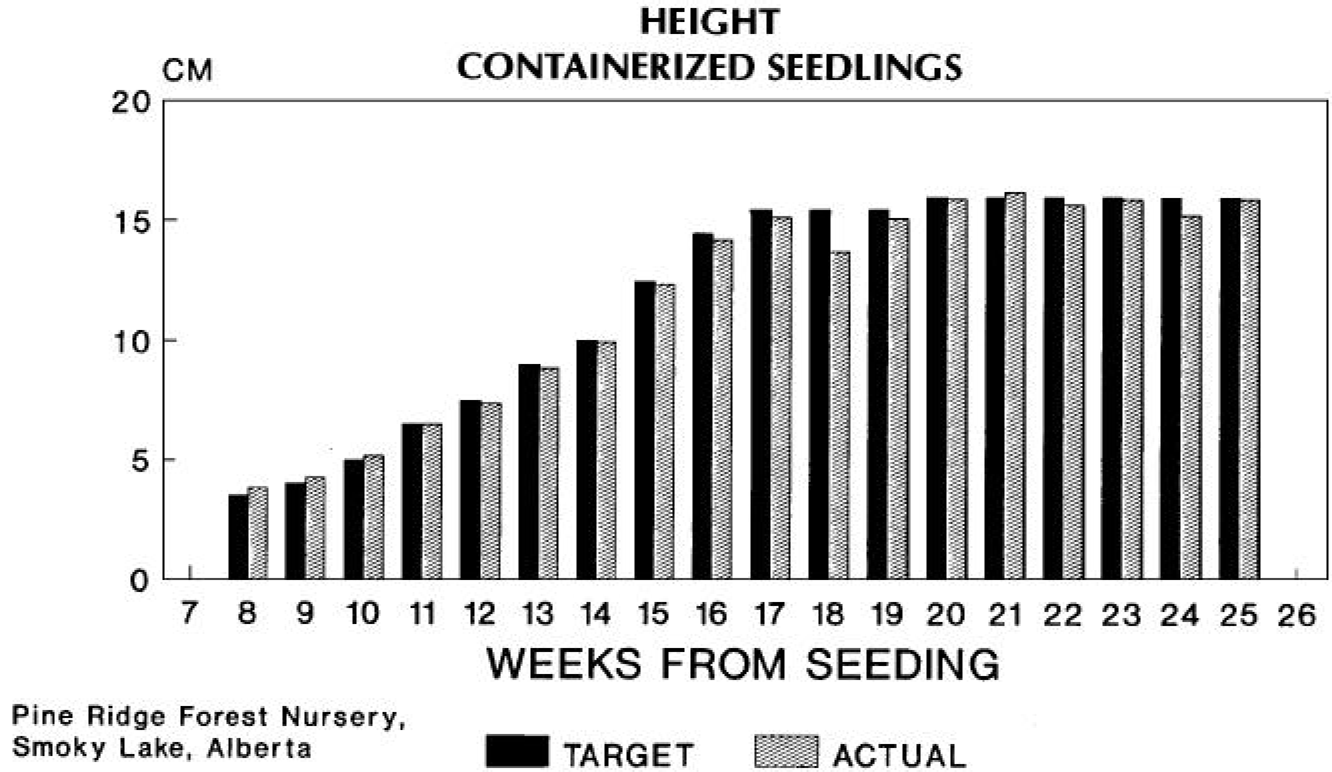

Figure 1.3—*Examples of target versus actual values for height and plant dry weight of white spruce containerized seedling, week 8 to week 25.*

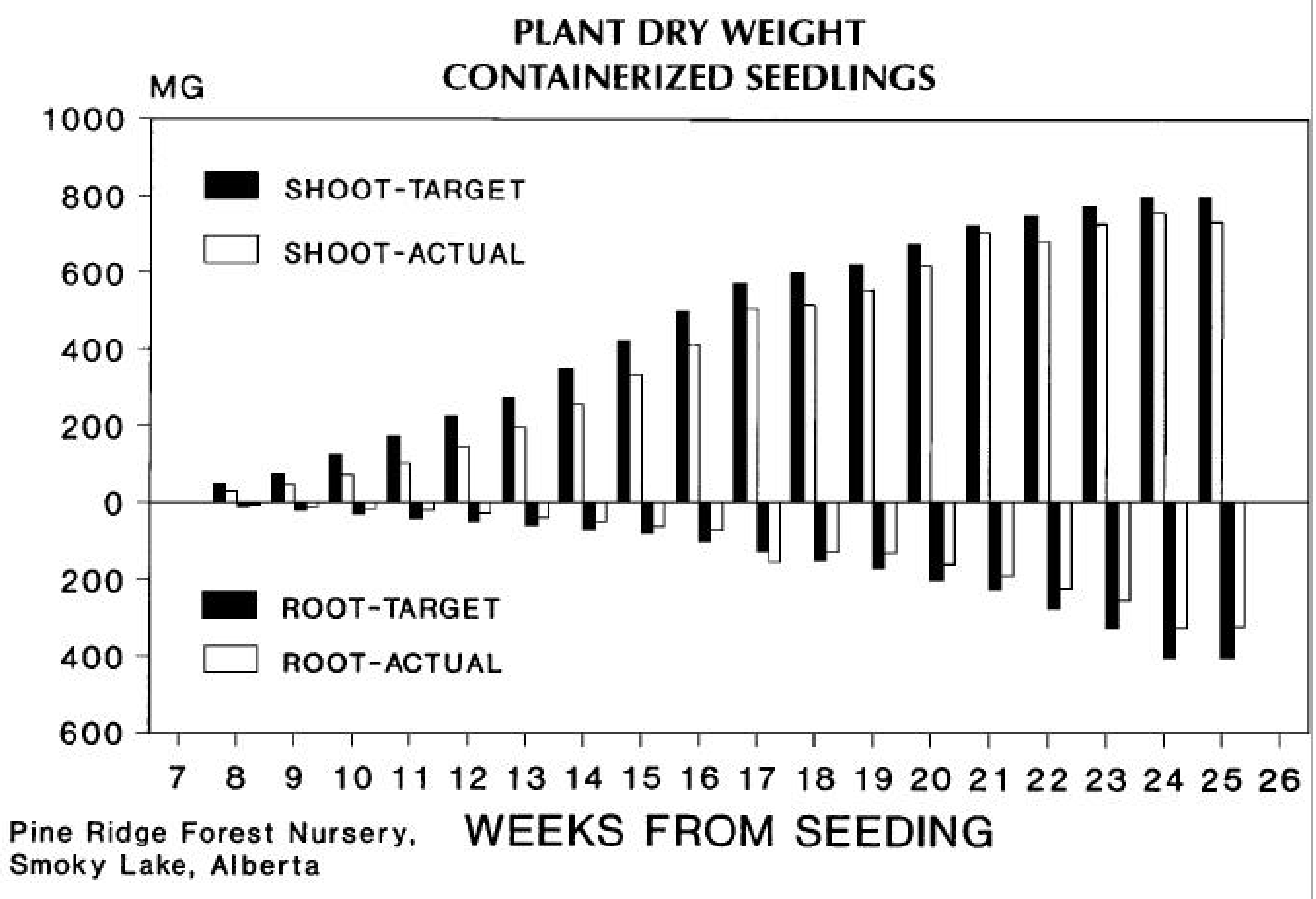

Figure 1.4—*Example of target versus actual values for plant dry weight of white spruce containerized seedlings from week 8 to week 25.*

standard for plantation performance. Target standards should be worked out in close cooperation with the nursery manager to ensure that observations of field performance result in a steady flow of improvements in quality of seedlings coming from the nursery.

1.6 The Future

The chapters that follow contain a great deal of information on some old and some very new seedling quality assessment techniques available to us. While height and caliper have served us well for decades, it is clear that we must continue to learn all we can about predicting future performance. It is no longer acceptable to look at morphology at lifting and expect that to always be a safe indicator of field performance.

Height, caliper, frost hardiness (LT_{50}), plant moisture stress (PMS), and root growth potential (RGP) will serve most grower and user needs (Chapters 3, 4, 5, 7, 8, 9). Target heights and calipers have been with us for a long time. In areas where the equipment is available, LT_{50} targets have been set to ensure that the seedlings are dormant and stress resistant enough to lift. Plant moisture stress is used extensively to monitor irrigation to achieve bud set without damaging seedling physiology and to control stress at lifting. Root growth potential has been used to target the best time to lift and plant seedlings.

Even with all that is known about the parameters that can be measured in seedlings, there is still very little that has been learned about what constitutes the best combination of traits. Parameters like root volume, fibrosity, shoot/root ratio, height/caliper ratio, nutrient levels and ratios, and others play a vital role in the survival and growth of a seedling after outplanting. Implicit in the target seedling concept is establishing minimum, maximum, and standard values for as many seedling parameters as possible and learning how to integrate and use the information in order to achieve a crop of target seedlings.

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