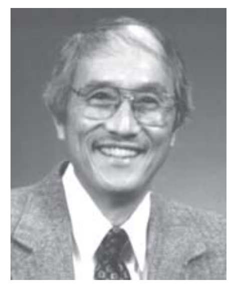
The Informed Buyer: Understanding Seedling Quality

Gary A. Ritchie
360-330-1725
gary.ritchie@weyerhaeuser.com
The G. R. Staebler Forest Resources Research Center
Weyerhaeuser Company
505 North Pearl Street
Centralia, WA 98531

Dedication



This paper is dedicated to my good friend and colleague of nearly 30 years, Dr. Yasuomi Tanaka, who passed away on October 23, 1999. Yasu was a tireless scientist, a steadfast friend and always The consummate gentleman. His contributions to nursery and reforestation science and practice here in the Pacific Northwest are destined to outlive all of us.

Abstract

The informed buyer should take stock quality into careful consideration when planning seedling purchases and reforestation activities. Seedlings have both morphological and physiological quality attributes, both of which can strongly affect field performance. Morphological attributes (stem diameter, height, etc.) are easily observed and measured and do not change during the lifting-planting season, so they form the basis of most stock grading systems. In contrast, physiological attributes, such as cold hardiness, stress resistance, root growth potential, photosynthetic efficiency and root viability are not visible and can change dramatically during the lifting-planting season, affecting stock quality in many ways.

Keywords

seedling height, stem diameter, nutrition, cold hardiness, dormancy, stress resistance, root growth potential, chlorophyll fluorescence, root viability

Introduction

It is no longer debated in reforestation circles that successful regeneration, whether it be with tree seedlings or with native plants, depends heavily on nursery stock quality. As our keynote speaker has pointed out, even with intensive site preparation, if stock quality is lacking survival and early growth often fall short of expectations.

Over the past 25 years I have conducted research in seedling quality and quality assessment in the Pacific Northwest. The remarks I have prepared for this conference reflect the insights and experiences gained over these years. The limited length constraints placed on this paper do not permit an exhaustive review of literature, although I have cited key papers in many topic areas. Nor is the paper a scientific treatise aimed at a technical audience. Rather, it is intended as a common sense review of some attributes of planting stock quality that have stood the test of time -- attributes that informed seedling buyers should understand. These fall broadly into two categories: morphological attributes and physiological attributes.

Morphological Attributes

Morphological attributes are readily visible. They include stem diameter, height, root system quality, foliage color, bud size, and other characteristics. They change little over the course of a lifting-planting season and form the basis of most stock grading systems worldwide. Many studies have found strong correlations between seedling morphology and field performance in many species (Mexal and Landis 1990 and references cited therein). Stem diameter, root system quality, and root/shoot balance seem to be particularly important.

To illustrate this point, we conducted a detailed experiment on the effect of stem diameter and root quality on survival and growth of Douglas-fir seedlings and rooted cuttings in Washington. Across eleven half-sib families and on three sites, larger diameter stock always outperformed smaller diameter stock, and within diameter classes, large fibrous root systems gave better performance than smaller, less fibrous root systems (Ritchie et al. 1993). Furthermore, these effects have persisted for at least five years.

David South (personal communication) showed with loblolly pine that not only does large diameter stock tend to perform best, but that the effect of stock quality and site prep intensity are additive. In other words, to get the biggest benefit from your site prep dollar, spend the extra money to plant the best stock.

Physiological Attributes

Physiological attributes rarely form the basis of any grading systems because they are essentially invisible and relatively difficult to measure. However, they are very important. A seedling which looks good but lacks, say, acceptable Root Growth Potential, may give very disappointing field performance. Physiological attributes change dramatically over a lifting-planting season as we will illustrate later. Fortunately, during the past several decades much has been learned about proper measurement and interpretation of physiological attributes. The remainder of this paper will focus on several which are central to stock quality.

Nutritional status

Sometimes during fall and winter, seedlings may appear “off color”, indicating poor nutritional status. This can result from crop hardening or frost protection practices. Nutrient deficiency can lead to poor performance. Fortunately, nutrient status is relatively easy to measure and there are many excellent references on this topic (e.g., Haase and Rose 1997). Table 1 contains ranges of values for many of the important nutrients from several plant types sampled in fall. The effects of nutrient deficiencies on plantation performance are discussed by van Den Driessche (1991).

Seedlings use carbohydrates (sugars and starches) as their primary food supply. Sugars are manufactured by photosynthesis and are stored in leaves, stems and roots as starch. In spring, seedlings mobilize these reserves for growth (Loescher et al. 1990). Carbohydrates are respired during cold storage (van den Driessche 1979) which may leave stock in a depleted state when planted (Ritchie 1982, Kim et al. 1997). Unfortunately, the forms and levels of carbohydrates needed for good survival and growth have not been determined. This is an active area of current research.

Table 1. Normal ranges of foliar nutrients for Douglas-fir seedlings in fall (Jones et al. 1991), and for plants in general.

	Percent of dry weight	
Element	Jones et al 1991	A&L Labs
N	1.50-2.30	1.40-2.00
P	0.18-0.35	0.10-0.40
K	0.75-1.10	0.50-1.50
Ca	0.30-0.50	0.25-2.00
Mg	0.09-0.15	0.12-0.40
S	0.15-0.25	0.10-0.30
	Parts per million	
B	4-15	15-40
Cu	3-12	4-25
Fe	70-200	50-200
Mn	200-600	25-500
Zn	25-45	20-150

Dormancy and stress resistance

Any gardener knows that you don't transplant bareroot plants when they are growing because they are extremely sensitive to stress – particularly root stress. However, when plants are in a certain state of dormancy they are very resistant to root stress. They can be lifted, handled, stored, and planted and expected to survive and perform well after planting.

Dormancy reaches its peak in October or November in this region. As dormant plants are exposed to temperatures in the range of 0° C to 10° C (32° F to 50° F) during winter, dormancy weakens. This weakening of dormancy by cold temperature is often called a "chilling requirement" and is well documented (Romberger 1963). Despite decades of research, the physiological mechanism of chilling requirements remains undiscovered (Seeley 1994). Once the chilling requirement is satisfied, usually sometime in February, dormancy is completely released and growth resumes as spring temperatures return.

The relationship between dormancy and stress resistance is not linear (Lavender 1985). While, dormancy is greatest in fall, stress resistance is greatest in mid-winter. Therefore, stock lifted in fall or spring can be expected to show low stress resistance, relative to stock lifted in winter (generally early December through February). For a seedling buyer, this is important to know.

Dormancy is also affected by cold or frozen storage. Both will slow down the release of dormancy and can be used to hold planting stock in a dormant and stress resistant state well into spring (Ritchie 1984). As an example, stock lifted in early December and held in frozen storage until April will remain dormant and stress resistant. In contrast, stock which is lifted in April will be resuming spring growth and will have lost stress resistance, hence, may be easily damaged by lifting and handling. This is one reason that cooler and freezer storage are used throughout the forest nursery industry.

Cold hardiness

Unfortunately, there is no good way to measure stress resistance. However, stress resistance is high when seedlings are cold hardy, and, fortunately, cold hardiness can be measured accurately, although the process is laborious and expensive (Ritchie 1991).

Figure 1 shows how cold hardiness, dormancy and stress resistance change through winter for Douglas-fir stock. Note that at peak dormancy, stress resistance and cold hardiness are very weak. Note also the similarity in timing between the stress resistance and cold hardiness curves. From this we believe

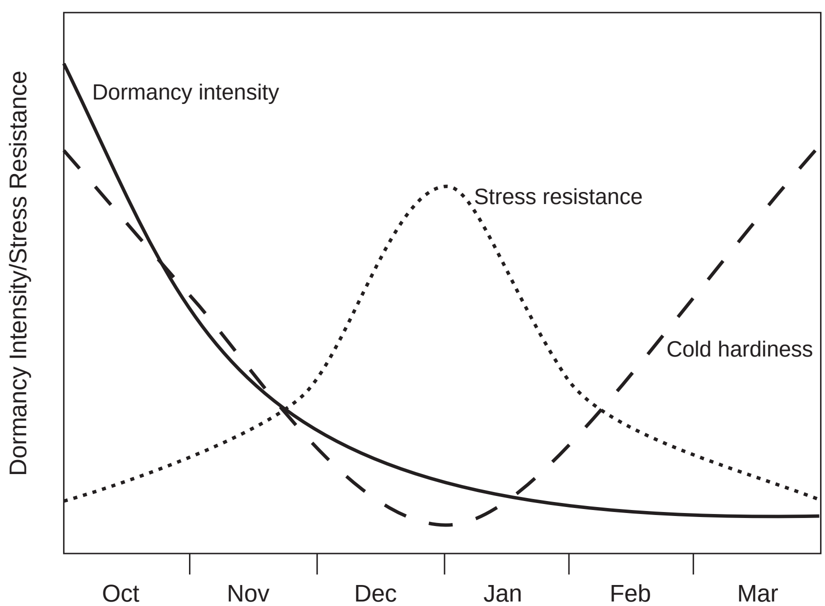


Figure 1. Dormancy intensity, stress resistance, and cold hardiness change dramatically over winter, with stress resistance and cold hardiness peaking more or less synchronously.

that cold hardiness can be used as a surrogate indicator of stress resistance.

Cold hardiness is also an important physiological attribute in its own right. If stock is grown late into fall, it may not have sufficient time to harden before winter. Early arctic events are common in this area, having occurred in four of the past 12 years in western Washington. In extreme cases, these can bring temperatures below –8° C (18° F), which is the minimum temperature for frost protection. When a freeze occurs stock may be damaged and the damage is not always immediately visible.

Different tissues within a plant have changing temperature sensitivities throughout winter. If an arctic event were to occur, say, in mid-November, it may kill cambium and buds but have no effect on needles. The stock may look healthy, but after planting the top may turn red and the buds may fail to break. So it is important that nursery stock be allowed to cold harden properly in fall. This is something the informed buyer should be aware of.

Finally, if stock is lifted for storage in late-November or early-December, before it has attained peak hardiness, then planted in January and exposed to damaging temperatures, the stock may be damaged or killed by such event.

Photosynthetic efficiency

Photosynthesis drives everything. In fact, without current photosynthesis some important conifers will not produce new roots (van den Driessche 1990). So photosynthetic efficiency would seem to be a good indicator of seedling quality. Any factors such as cold damage, disease, or poor nutrition, which impair photosynthetic efficiency, can seriously impact seedling vigor and performance.

Photosynthetic efficiency can be measured by determining the amount of CO_2 taken up by leaves and calculating uptake per unit of leaf area. However, this is very tedious and requires expensive equipment and very careful attention (Leverenz and Hallgren 1991).

A newer method called “Chlorophyll Fluorescence” (CF) holds great promise as a rapid, non-destructive measure of photosynthetic efficiency (Mohammed et al. 1995). Several labs are now working to develop CF-based tests that might be used to assess planting stock vigor, to diagnose damage and to predict field performance. This work is yielding very promising results. I believe that soon (CF) will be an important stock quality indicator that will be readily measurable and reported along with nutrition, dormancy status and cold hardiness.

Root growth potential (RGP)

Perhaps the most widely reported seedling quality attribute is Root Growth Potential (Ritchie and Tanaka 1990). This is essentially a bioassay in which a seedling’s ability to grow roots is determined in an environment near optimum for root growth. When seedlings do not produce roots, or produce relatively few, it signals that something is wrong.

An RGP test should be interpreted like a seed germination test. Both are conducted under near optimum conditions and measure seed or stock performance under these conditions only. They do not necessarily predict germination following sowing into the nursery or root growth following planting into the field. If seed germinates poorly in a lab test, or if seedlings show poor RGP, both indicate a problem.

Some have misused RGP information. For example they have used it to predict field root growth or even survival and growth after planting (see Simpson and Ritchie 1997). Much of the disenchantment expressed in the literature about RGP (e.g., Binder et al. 1988) reflects its inadequacies in this area. RGP indicates stock viability only, it does not necessarily predict field performance.

Root viability

Viability of root systems is essential for good stock performance. Root viability can be disrupted by waterlogged soils or growing medium, poor nutrition, prolonged storage, pathogens, cold damage, rough handling and other agents. Dead roots can be recognized simply by scraping away root bark and looking for black or brown, mushy tissue. Quantitative tests are now being developed to assess root viability based on leakage of electrolytes (McKay 1992) and tissue water relations (Ritchie 1990). None of these tests are yet operational.

Other Stock Quality Considerations

There are other stock quality attributes such as insect and disease damage, seedling water status, and various biochemical indicators that I have not mentioned. I did not discuss insects and diseases because they were the subject of the previous talk. I also did not discuss plant water relations, not because they are not important, but because we don't have any good guidelines on which parameters to measure and what values are normal or abnormal. Other tests and indicators are being developed but are not yet operational.

Integration and Interpretation

It is important to keep all of this information in perspective. Stock quality is key to stock performance, and there are many indicators and tests of stock quality. Different tests may give different results on the same stock. For example, stock may have very high RGP and very low cold hardiness yet be perfectly viable. The informed buyer takes these tests and this information seriously, but understands that they are neither perfect nor comprehensive and uses them with intelligence and wisdom.

Literature Cited

Binder, W. D., R. K. Scagel and G. J. Krumlik. Root growth potential: facts, myths, value? Proceedings of the 1988 Combined meeting of the Western Forest Nursery Associations, Vernon, B. C., Canada, pp. 111-1187. T.D. Landis ed. U.S.D.A. Forest Service Gen. Tech. Report RM-167.

Haase, D. L. and R. Rose. 1997. (Eds.) Symposium Proceedings: Forest seedling nutrition from the nursery to the field. Nursery Technology Cooperative, Oregon State University, Corvallis.

Jones, J. B., B. Wolf, and H.A. Mills. 1991. Plant analysis handbook. Micro-Macro Publishing, Inc.

Kim, Y. T., C. Glerum D. F. Hickie and C. P. Chen. 1997. Effects of cold storage duration on carbohydrate and amino acid concentration, root growth potential, and growth of jack pine and black spruce seedlings. Ontario Ministry of Natural Resources, Forest Research Report No 143, 18 p.

Lavender, D. P. 1985. Bud dormancy. Proceedings, Evaluating seedling quality: principles, procedures, and predictive abilities of major tests, pp. 7-15. M. L. Duryea (ed.). Forest Research Laboratory, Oregon State Univ., Corvallis.

Leverenz, J. W. and J-E. Hallgren. 1991. Measuring photosynthesis and respiration of foliage. Techniques and approaches in forest tree ecophysiology, pp. 303-328 J. P. Lassoie and T. M. Hinckley (eds.), CRC Press, Boca Raton, FL.

Loescher, W. H., T. McCamant and J. D. Keller. 1990. Carbohydrate reserves, translocation, and storage in woody plant roots. HortScience 25:274-281.

Long, A. J. and B. D. Carrier. 1993. Effects of Douglas-fir 2+0 seedling morphology on field performance. New Forests 7:19-39.

McKay, H.M. 1992. Electrolyte leakage from fine roots of conifer seedlings: a rapid index of plant viability following cold storage. Canadian Journal of Forest Research 22:1371-1377.

Mexal, J. G., and T. D. Landis. 1990. Target Seedling Concepts: Height and Diameter, Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forestry Nursery Associations, August 12-17, 1990, Roseburg, OR. pp. 17-36, (eds.) R. Rose, S.J. Campbell and T.D. Landis. USDA Forest Service Gen. Tech. Rep. RM-200.

Mohammed, G. L., W. D. Binder and S. L. Gillies. 1995. Chlorophyll fluorescence: a review of its practical forestry applications and instrumentation. Scandinavian Journal of Forest Research 10:383-410.

Ritchie, G. A. 1982. Carbohydrate reserves and root growth potential in Douglas-fir seedlings before and after cold storage. Canadian Journal of Forest Research 14:186-190.

Ritchie, G. A. 1984. Effect of freezer storage on bud dormancy release in Douglas-fir seedlings. Canadian Journal of Forest Research 14:186-190.

Ritchie, G. A. 1990. A rapid method for detecting cold injury in conifer seedling root systems. Canadian Journal of Forest Research 20:26-30.

Ritchie, G. A. 1991. Measuring cold hardiness. Techniques and approaches in forest tree ecophysiology, pp. 557-582. (eds.) J. P. Lassoie and T. M. Hinckley, CRC Press, Boca Raton, FL.

Ritchie, G. A. and Y. Tanaka. 1990. Root growth potential and the target seedling. Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forestry Nursery Associations, August 12-17, 1990, Roseburg, OR. pp. 37-51. (eds.) R. Rose, S.J. Campbell and T.D. Landis. USDA Forest Service Gen. Tech. Rep. RM-200.

Ritchie, G. A., Y. Tanaka, R. Meade and S. D. Duke. 1993. Field survival and early height growth of Douglas-fir rooted cuttings: relationship to stem diameter and root system quality. Forest Ecology and Management 60:237-256.

Romberger, J. A. 1963. Meristems, growth and development in woody plants. U.S.D.A. Forest Service Technical Bulletin No. 1293, 214 p.

Seeley, S. D. 1994. Dormancy – the black box. HortScience 29:1248.

Simpson, D. G. and G. A. Ritchie. 1997. Does RGP predict field performance? A debate. New Forests 13:253-277.

van den Driessche. R. 1979. Respiration rate of cold-stored nursery stock. Canadian Journal of Forest Research 9:15-18.

van den Driessche, R. 1990. Importance of current photosynthate to new root growth in planted conifer seedlings. Canadian Journal of Forest Research 17:776-782.

van den Driessche, R. 1991. Effects of nutrients on stock performance in the forest. Mineral nutrition of conifer seedlings, pp. 230-260 (ed.) R. van den Driessche. CRC Press, Boca Raton, FL.