When to Measure Seedling Quality in Bareroot Nurseries[1]

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Abstract.--Quality of bareroot conifer nursery stock is measured (1) during the growing phase, (2) before lifting, and (3) before outplanting. The appropriate tests to make at each times are discussed.

Seedling quality can be described or measured using a wide range of techniques and procedures (Burdett 1983; Chavasse 1980; Ritchie 1984). The rationale for assessing seedling quality, in particular, the principles and procedures for those seedling quality tests presently used on an operational basis are summarized in Ken Munson's paper (this proceedings).

The purpose of my paper is to discuss which, and perhaps more importantly, when are these seedling quality tests used in bareroot nurseries. In the bareroot seedling production cycle, there are three phases when seedling quality tests are used: (1) during the growing season, (2) prior to lifting, and (3) prior to field planting.

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MEASURES MADE DURING THE GROWING SEASON

Measurement of seedling quality, particularly seedling material attributes (Ritchie 1984) during the growing season, can help the nurseryman produce a maximum number of saleable seedlings. Morphological measurements of height, stem diameter and dry weights when taken at intervals over a growing season can be used to generate growth curves (fig. 1) for crops. These curves, when repeated for several years, can provide a reasonable prediction of crop inventories. As well, "fine tuning" of fertilizer, root culturing and irrigation regimes can be made so that the maximum number of target quality seedlings are produced.

In British Columbia, tissue nutrient levels (N:P:K:Ca:Mg) of 1+0 Douglas-fir (coastal and interior varieties), white spruce, lodgepole pine and Sitka spruce have been determined annually in mid-October since 1968 (van den Driessche 1984). The results of these tests when considered along with the size of the 1+0 seedlings, the target sizes of the 2+0 crop and the "normal" nutrient levels for a particular species x nursery combina-

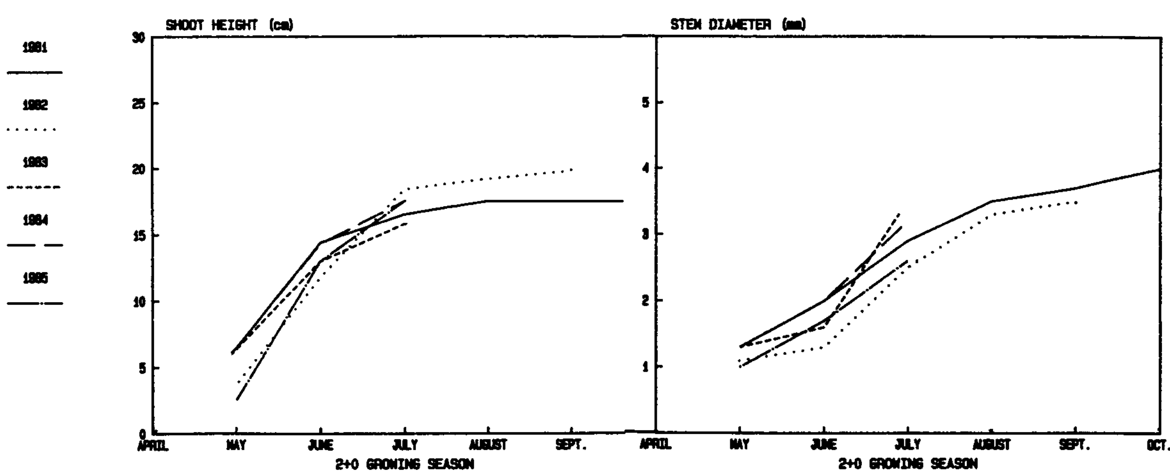

Figure 1.--Shoot height and stem diameter growth of 2+0 interior spruce bareroot seedlings at Skimikin Nursery, Salmon Arm, B.C. Each sample point represents 200 to 250 seedlings.

tion are used to develop the fertilizer regime for the second growing season.[3] Nutrient analysis during the growing season is usually used to determine if deviations in projected growth rates, or physical abnormalities, such as chlorosis, are nutrient-related.

For operational use, the most common means to assess plant moisture stress is to measure xylem pressure potential (XPP) using the pressure chamber method (Cleary and Zaerr 1980; Ritchie and Hinckley 1975; Waring and Cleary 1967). Moisture stress applied during the growing season has been reported to result in growth reductions in several conifer species (Dykstra 1974; Glerum and Pierpoint 1968; Kaufmann 1977; Schulte and Marshall 1983; Timmis and Tanaka 1976; Young and Hanover 1978). The effectiveness of plant moisture stress as a cultural tool to manipulate seedling growth may interact with daylength. Blake et al. (1979) noted that mild moisture stress (pre-dawn xpp of -0.4 to -0.8 MPa) was most effective in reducing shoot:root ratios and apical height growth, while increasing root mass and stem diameter if the stress was applied in mid-July before natural daylengths shortened. Moisture stress may also be a useful cultural tool in the "hardening" process, particularly with those conifers indigenous to regions with mid-summer drought, which do not respond quickly to shortening daylengths, or are grown in nurseries with longer daylengths (Lavender 1985). Young and Hanover (1978) found dormancy could be imposed using water stress in Colorado blue spruce, even under 24-hour days; however, this imposed dormancy (quiescence) was released on re-watering. Proleptic, or lammas growth in Douglas-fir can also be limited by water stress (Blake et al. 1979).

With the exception of cold hardiness determinations, performance attributes (Ritchie 1984) are not usually measured during the growing season. Nurseries experiencing frosts early or late into the growing seasons often undertake cold hardiness testing to determine if irrigation for frost protection is required.

MEASURES MADE PRIOR TO LIFTING

Seedling quality assessments made at this time are done so for two reasons: (1) to describe the stock quantity and quality for the nursery customer, and (2) to ensure seedlings destined for cold/frozen storage are lifted at a time of maximum "storability".

Material attributes, such as standard morphological assessments, and in some cases, special measurements of resting bud gross morphology (Thompson 1985) or needle primordia number (Colombo and Odlum 1984; Colombo et al. 1982) are appropriately measured at this time. Tissue nutrient analysis can be done as there may be field performance benefits obtained from increased tissue nutrient levels (Landis 1985). Moisture stress (XPP) at lifting can have adverse effects on field performance of stored seedlings (Daniels 1978). Monitoring of XPP using the pressure chamber method (Cleary and Zaerr 1980; Ritchie and Hinckley 1975; Waring and Cleary 1967) during the lifting period would seem a worthwhile process to minimize the stresses associated with lifting, sorting and grading of nursery stock (Burdett and Simpson 1984).

Choice of lifting date can be based on a number of factors: operational considerations, such as staff availability and nursery field access; past experience, or "lifting windows" for specific seedlot x nursery combinations (Jenkinson 1984); or some measure of seedling physiology (Burdett and Simpson 1984) which predicts post-storage vigor or field performance potential. It is immaterial which means of deciding on a lifting date is used so long as the method(s) selected ensure the seedlings provided to the customer at planting time will survive and grow.

In British Columbia, past experience too often has been found to be an unreliable means of determining a lifting date to ensure optimum poststorage seedling vigor. The lifting window method (Jenkinson 1984) used with apparent success in California and the chilling hour accumulation methods used in Ontario (Mullin and Hutchinson 1978) have not been widely used in British Columbia principally because of the large number (>1500) of seedlots and species (17) grown in our nurseries. The wide geographic (48.5 to 60°N and 114 to 139°E) and considerable elevational range (0-2000 m) of seed origins would require considerable effort to generate seed source lifting windows. Thus, it was for both practical and philosophical reasons that research effects were directed towards consideration of several physiological variables which may predict post-storage because of a direct causal relationship, or simply by correlation.

Dormancy and tissue cold hardiness appear to be the most useful performance attributes measurable prior to lifting (Garber and Mexal 1980; Burdett and Simpson 1984). Several techniques to measure dormancy have been used, and are reviewed by Lavender (1985) and Ritchie (1984). Mitotic activity of meristematic shoots (buds), a material attribute, may be a useful tool for predicting when to lift conifer seedlings as Carlson et al. (1980) observed a reduction of mitotic activity in Douglasfir as fall progressed. Further research is needed, however to ascertain the predictive value of prelift mitotic activity measurements as a means of deciding when to lift to overwinter storage. Dormancy release index (Ritchie 1982, 1984; Ritchie and Dunlap 1980) also may be a useful tool in choosing lifting dates. Dormancy release index measurement, however, requires 10 to 60 days. This time requirement limits the practical application of the technique.

Cold hardiness has been implicated as being correlated with seedling storability and thus may be useful in choosing lifting dates (Burdett and Simpson 1984). Several methods of measuring

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tissue cold hardiness are available and have been amply reviewed by Glerum (1985), Ritchie (1984), Timmis (1976) and Warrington and Rook (1980). Presently in British Columbia, an operational prelifting cold hardiness testing program has sampled seedlings from nearly 25 nurseries. The test utilizes a controlled freeze at 6°C hr^{-1} to -18°C followed in 4 to 10 days by an assessment of foliage mortality. If foliage mortality due to the freezing test is less than 25%, seedlings are judged suitable for lifting to overwinter (ca. 4 to 8 months) frozen (-2°C) storage. The accuracy of the lifting recommendations are checked by determining root regeneration potential after 6 months, -2°C cold storage. In Ontario, an electrical conductivity method (Colombo et al. 1984) of measuring cold hardiness is used to determine if seedlings are sufficiently hardy to overwinter out-of-doors. These conductivity methods, along with the more rapid differential thermal analysis (DTA) technique (Becwar et al. 1981; Sakai 1979, 1982; Wallner et al. 1982) are presently being evaluated as quicker (6 to 48 hours) methods of assessing cold hardiness such that safe lifting dates can be selected.

MEASURES PRIOR TO PLANTING

Fall and winter lifted seedlings that receive overwinter cold storage may exhibit moisture stress in storage if lifted when under moisture stress, packaged incorrectly such that tissue water is lost, or subject to temperature fluctuations during the storage period so that water condenses on the inside of the multi-wall liner bags. The pressure chamber technique has proved a useful monitoring tool to ensure proper lifting, storage and handling practices are followed. In my experience, it is very rare to find overwinter stored seedlings with XPP levels less than -0.5 MPa unless gross mishandling has occurred. On the planting site, however, bareroot seedlings are susceptible to moisture loss during the handling process which may impede growth (Coutts 1982). Using the pressure chamber on the planting site can serve to educate field staff as to their handling effects on seedling water relations. It should be noted, however, that whole plant XPP may not be a sensitive enough measure to detect damage to fine roots (Coutts 1981).

Presently, there are only two performance attributes which are used to measure seedling quality at, or shortly before, planting. The vigor test developed at Oregon State University (Hermann and Lavender 1979) has been shown (McCreary and Duryea 1985) to be well correlated with field survival. Unfortunately, in many circumstances, the 30 days required for damage to develop limits the usefulness of this test. Root growth potential (RGP) testing (Ritchie 1985) using a variety of test conditions and durations has shown generally strong correlation to field performance (Day 1982; Sutton 1980, 1983; Burdett 1979; Burdett et al. 1983; Ritchie and Dunlap 1980). Ritchie (1985) describes the tests developed by Stone and his colleagues (Stone 1955; Stone and Schubert 1959(a), 1959(b); Stone and Jenkinson 1970). The standard RGP test requires 28 days; in British Columbia, a 7-day test period has been found adequate for growth of large numbers of new roots in most species x stock types. The RGP test conditions are somewhat arbitrary, but should be chosen such that (1) the strongest correlations with field performance are obtained, and (2) the best differentiation between low and medium vigour stock is attained. For lodgepole pine, 30°C day/25°C night temperature regimes and a 16-hour day with a photosynthetic photon flux density (PPFD) of 400 mol $s^{-1}m^{-2}$ seem to produce the most number of new roots (Burdett 1979), while for white spruce and Douglas-fir, cooler regimes appear to result in greater numbers of new roots (figs. 2 and 3). Present operational practice in British Columbia is to use the warmer 30°C/25°C regimes for all species as satisfactory correlation between RGP and field performance has been demonstrated in our major species (spruce, lodgepole pine, Douglas-fir) (Burdett et al. 1983; Simpson unpubl. data) at these temperatures, and all species grown in British Columbia have been observed to produce roots at these temperatures. Research underway may, however, result in changes to these conditions in the future if better correlation with field performance and/or better differentiation of low and medium vigour seedlots can be obtained.

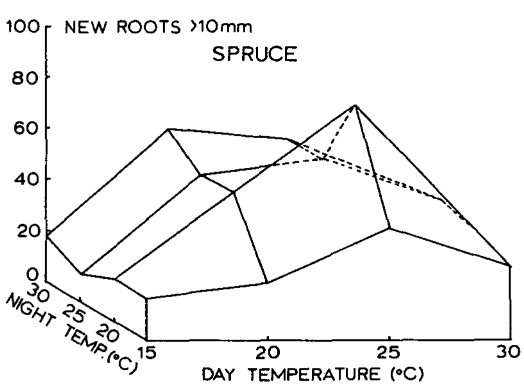

Figure 2.--Day/night temperature regime effects on root growth potential (RGP) of Engelmann spruce container-grown seedlings. Each sample point represents the mean number of new roots >10 mm in a 16-seedling sample.

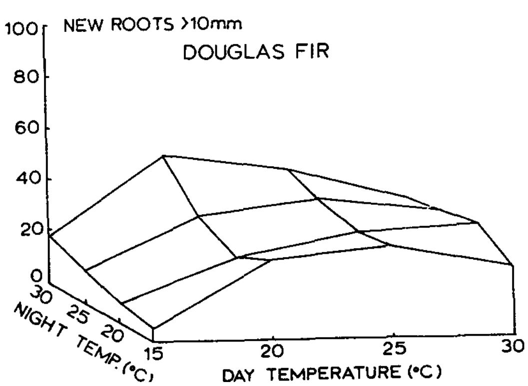

Figure 3.--Day/night temperature regime effects on root growth potential (RGP) of Douglas-fir (interior variety) container-grown seedlings. Each sample point represents the mean number of new roots >10 mm in a 16-seedling sample.

SUMMARY

In bareroot nurseries, seedling quality should be measured using the appropriate tests and during the appropriate phases of the production cycle, these are:

Production phase	Quality test	Operational objective(s)
Growing	- Morphology	- Production targets from curves
	- Nutrient levels	- Ensure maximum growth rates - Avoid deficiencies/excesses
	- PMS	- Ensure maximum growth rates - Dormancy induction
	- Cold hardiness	- Frost protection
Pre-lifting	- Morphology	- Stock descriptions
	- Nutrient levels	- Possible correlation to field performance
	- PMS	- Avoid stress at lifting
	- Dormancy status	- Predict storability
	- Cold hardiness	- Predict storability
Pre-planting	- PMS	- Avoid storage and handling stress
	- Vigour test	- Correlated with field performance
	- RGP	- Correlated with field performance

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