# Principles, Procedures, and Availability of Seedling Quality Tests[1]

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Abstract.--As seedling quality tests move from the research to the operational realm, users and potential users must become knowledgeable about the basis for various tests. Without a basic understanding, vigor testing will remain a black-box. This paper condenses and reviews the principles and procedures behind measurements now considered operational: Morphology, mineral nutrition, water status, frost-hardiness, survival, dormancy release, and root growth potential. Tests are now available from three private companies and one university. Seedlings sent for testing should be representative of the lot, and transported in such a way that vigor is not reduced. Cooperative studies to correlate test results and seedling performance in the field are encouraged. The potential benefit of seedling quality testing can be very high relative to the cost.

## INTRODUCTION

Seedling quality is a topic that has been discussed by nursery managers and reforestation foresters for several decades. Morphological traits were the focus of early seedling growers and users, while recently the emphasis has been on physiological quality, or vigor. Many methods used to characterize seedling quality that heretofore were experimental are now being used as operational tests. Different tests and different reasons for testing are being employed. At this point in time the usefulness of these tests as a measure of seedling vigor is based on both intuitive reasoning and empirical evidence.

Operational vigor tests, for such seedling features as frost-hardiness and root growth potential, have been available for only a few years. There is most likely some confusion about the principles and procedures of the various tests. Many potential users probably view vigor testing as a "black box", and are hence rather skeptical to the notion of using vigor tests as a means of quantifying seedling quality.

The purpose of this paper is to help clarify the issue by briefly reviewing the rationale for seedling quality testing, the tests that are now available on an operational basis, and the principles and procedures upon which the tests are based. Finally, a listing of organizations which offer a seedling testing service, and sampling and shipping recommendations are provided.

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## RATIONALE FOR SEEDLING QUALITY TESTING

There are several reasons for testing seedling quality (Faulconer and Thompson 1985; Duryea 1985). From the perspective of a nursery manager, test results can be used to:

- Demonstrate stock quality to a customer.
- Guide the implementation of certain practices.
- Assess the affects of certain practices.
- Cull seedling lots that have a low expected field performance.

On the other hand, a seedling user (regeneration forester) might use test results to:

- Match seedlings with certain characteristics to specific sites.
- Identify if, and at what step, seedling quality falldown occurs during the handling and planting phase.
- Cull seedlings of low vigor before the cost of planting has been incurred.
- Determine if special handling practices are necessary.
- Determine if plantation success or failure was due to stock quality or other factors.

## OPERATIONAL TESTS

Many procedures for characterizing seedling quality have been tested (Ritchie 1984), some with more success than others. In his review, Ritchie proposed a logical separation of seedling attributes for which measurements can be made : material attributes and performance attributes. Following is a modified list of these attributes for which tests are considered operational:

| Material Attributes | Performance Attributes |
|---|---|
| o Morphology | o Frost-Hardiness |
| o Height, stem diameter | o Survival - Unstressed |
| | o Survival - Stressed |

A few of these measurements require only limited equipment and can be made at the nursery or in the field. Most of the measurements, however, require trained personnel, rather expensive equipment and/or a facility for maintaining constant environmental conditions.

It is important that a user of test information have an understanding or at least an appreciation for the biological basis of each test. Only under this condition can useful interpretations of the data be made.

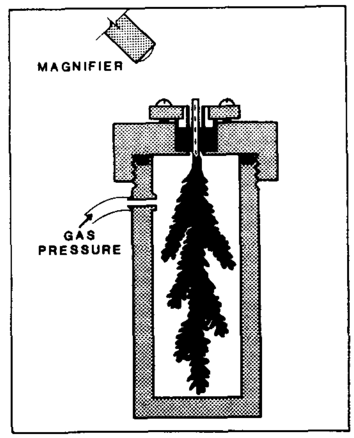
## PRINCIPLES AND PROCEDURES

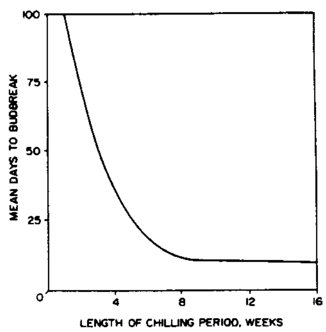
As noted earlier, one purpose of this paper is to capsulize the principles and procedures of the tests that are now considered to be operational. Information about each test will be presented in table form; the reader is referred to specific references for more detail about specific tests.

The following extended table lists the principle(s) upon which a test is based, and a simplified procedure for taking a measurement. This is not intended to serve as a user's guide to vigor testing, but rather an overview from which more detailed inquiries can be made.

**Table 1.--Principles upon which seedling quality testing is based, along with simplified measurement procedures.**

| Attribute | Principle | Procedure | Reference |
|---|---|---|---|
| Morphology | | | |
| o Height | o Correlated to needle number, thus a measure of photosynthetic capacity and transpirational area.<br>o Positive relationship between height growth and initial height. | o Meter stick, electronic device<br>o Standard position; e.g., cotyledonary scar to base of bud. | Thompson, 1985 |
| o Diameter | o Better correlated than height to survival.<br>o Good correlation with dry weight.<br>o Larger diameter, more structural support and protection. | o Vernier caliper or simple guage.<br>o Measure at a standardized position.<br>o Stem cross-section is not a uniform diameter. | Thompson, 1985 |
| o Dry Weight | o Correlated to survival and growth as are height and diameter.<br>o Good relationship with photo-synthetic area.<br>o Destructive technique.<br>o Easier to use height and/or diameter. | o Rinse tissue, oven dry.<br>o 65° C, 24 hours.<br>o Weigh samples on a balance.<br>o Weigh shoot and root separately to determine ratio. | Thompson, 1985 |
| o Shoot/Root | o Measure of balance between the transpirational area (shoot) and the water absorbing area (root).<br>o Contradictory as an index of field performance. | o Dry weight or volume displacement method.<br>o Shoot weight divided by root weight. | Burdett, 1979 |
| o Bud Height | o Correlated with number of needle primordia and field growth.<br>o Related to vigor at time of dormancy induction. | o Sever bud at base.<br>o Measure with vernier calipers. | Thompson, 1985 |
| Mineral Nutrition | o Certain mineral elements are essential components of plant structure or biochemical functions.<br>o Deficiency of an element will reduce vigor and growth. | o Take good, clean, representative samples.<br>o Stem and foliage for 1-0's, foliage only for older stock.<br>o Oven dry, 65° C, 24 hours.<br>o Grind, dry ash, analyze. | Landis, 1985 |

| Attribute | Principle | Procedure | Reference |
|---|---|---|---|
| Water Status | o Water required to maintain tugor, transport nutrients, facilitate biochemical processes.<br>o If water potential = 0, a plant's water requirements are fully satisfied.<br>o As water content decreases, w.p. becomes more negative (now expressed as megapascals, 1 MPa = 10 bars).<br>o Primary use in irrigation scheduling, dormancy induction and in lifting operation. | o Pressure chamber method.<br><br><br>o Place leaf or stem in chamber.<br>o Increase pressure in chamber with compressed $N_2$ gas until sap appears at cut surface.<br>o Record pressure on guage. | Joly, 1985 |
| Frost-hardiness | o The susceptibility of seedlings to freezing damage changes naturally with the seasons and artificially with cultural practices.<br>o Hardier seedlings are more resistant to lifting, handling and planting stresses.<br>o Freeze damage is usually dehydration.<br>o Rate of temperature drop and time at minimum temperature are important variables in the test. | o Sample whole seedlings.<br>o Place seedlings in a freezer with a lower minimum temperature of at least -25° C.<br>o Begin at 0° C, drop at 5° C/hr, hold at minimum temperature for 2 hours, raise at 10° C/hr.<br>o Run at 3 temperatures (use fresh samples each time) that bracket $LT_{50}$ (temperature at which 50% die).<br>o Hold seedlings in greenhouse for 1 week, allowing time for damage symptoms to appear.<br>o Evaluate and assign a damage index rating to buds, needles and stem.<br>o Plot numbers on graph paper and interpolate $LT_{50}$.<br>o Seedlings can also be evaluated with an electrical conductivity meter after freezing.<br>o Uniform test conditions are important. | Glerum, 1985 |
| Dormancy Release | o Dormancy develops in response to environmental signals, but can be influenced by cultural practices.<br>o For seedlings to have maximum vigor, their annual cycle must be in phase with the natural environment.<br>o Relationship between chilling period and days to bud break (refer to graph on next page). | o Whole seedlings are potted and placed in a greenhouse, 20-25° C, 16 hr. daylength.<br>o Held for a set period of time (usually 28 days) and evaluated for terminal and lateral bud burst.<br>o Often done in conjunction with the 28-day root growth potential test.<br>o Data presented as % terminal bud break. | Lavender, 1985 |

| Attribute | Principle | Procedure | Reference |
| --- | --- | --- | --- |
| Dormancy Release (Con't) | <br>o Once chilling requirements have been met, buds become active in response to rising temperatures. | | |
| Survival (Unstressed) | o Observe seedlings under ideal growth conditions.<br>o Should reveal the capacity or potential of a lot to survive. | o Pot 20-30 whole seedlings (or some representative sample), place in a greenhouse.<br>o 20-25° C, 16 hr daylength, 28 days to 2 months.<br>o Tally living and dead seedlings, express as % survival. | McCreary and Duryea, 1985 |
| Survival (Stressed) | o Assumes the normal stresses encountered during planting and first-year establishment can be roughly simulated by exposing seedlings to artificial stress.<br>o Roots are probably the most susceptible to damage. | o Sample 30 seedlings, wash roots, pat dry.<br>o Suspend seedlings in a hot, dry chamber or room.<br>o 32° C, 30% humidity, 15 min.<br>o Remove seedlings, place in water for 5 min.<br>o Evaluate for mortality after 2 weeks, 1 month, and 2 months.<br>o Usually done in conjunction with 30 unstressed seedlings. | McCreary and Duryea, 1985 |
| Root Growth Potential | o Outplanting survival is often a function of how quickly a seedling re-establishes the intimate contact of its roots with the soil.<br>o This is accomplished by initiating and elongating roots.<br>o RGP is a measure of a seedling's capacity to do so under ideal growing conditions.<br>o RGP accumulates in the nursery and is expressed the following year in early spring.<br>o RGP can be influenced by nursery environment, and cultural and and handling practices.<br>o Good correlations between RGP (at planting) and survival and growth.<br>o Hypothesized that the relationship between RGP and field performance is due to a close linkage between RGP, cold-hardiness, and stress resistance, rather than growth of new roots *per se*. | o Select 20-30 seedlings that represent the lot to be tested.<br>o Wash the roots and pot with a 1:1 mix of peat or perlite : vermiculite.<br>o Water the pots initially, and keep near field capacity.<br>o Place in a greenhouse and maintain as uniform environmental conditions as possible.<br>o 20° or 25° C day/night temperature and 16 hr daylength is satisfactory.<br>o RGP is sensitive to temperature, moisture and light.<br>o After 28 days, quantify new root growth.<br>o Total counts or length measurements may be used, but for practical purposes, tallying root codes is satisfactory. | Ritchie, 1985 |

| Attribute | Principle | Procedure | Reference |
|---|---|---|---|
| Root Growth Potential (Con't) | o RGP is presently the most widely used performance attribute of seedling quality. | Example:<br>Code — Description<br>0 — No new roots<br>1 — Some <1 cm<br>2 — 1- 10>1 cm<br>3 — 11- 30>1 cm<br>4 — 31- 60>1 cm<br>5 — 61-100>1 cm<br>6 — 100+ >1 cm<br>o Data can be averaged or expressed as a frequency distribution.<br><br>Alternate Methods<br>o 7-day growth room test.<br>o 7 or 28 day hydroponic test.<br>o Shorter tests are done at higher temperatures; e.g., 25-30° C. | |

ORGANIZATIONS OFFERING SEEDLING TESTING SERVICES

Table 2 lists the organizations which now offer a range of seedling testing services in the northwest. Most organizations are flexible enough to accommodate special services or handling practices when given advance notice.

Seedling water status is usually measured at the nursery or outplant site. The procedure requires a "pressure chamber," which can be purchased from PMS, Inc. in Corvallis, Oregon (503/752-7926, cost is roughly $1,500).

Table 2.--Organizations offering a range of seedling testing services in the Northwest.

| | TESTS AVAILABLE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | RGP 28-day | RGP 7-day | Frost-Hardiness | Morphology | Dormancy Release | Survival Un-Stressed | Survival Stressed | Frost Damage Assessment | Special Services |
| 1. International Paper Co.<br>34937 Tennessee Rd.<br>Lebanon, OR 97355<br>Contact: Ken Munson<br>503/243-3273<br>Jay Faulconer<br>503/259-2651 | X | | X | X | X | X | | | X |
| 2. Seedling Quality Services<br>6511 203rd Ave. S.W.<br>Centralia, WA 98531<br>Contact: Sally Johnson<br>206/273-9882 | X | | X | X | X | X | | X | X |
| 3. MacMillan-Bloedel Ltd.<br>65 Front St.<br>Nanaimo, BC V9R 5A9<br>Contact: Glen Dunsworth<br>604/753-1112 | | X | X | X | X | X | X | | X |
| 4. Oregon State University*<br>Dept. of Forest Science<br>Corvallis, OR 97331<br>Contact: Doug McCreary<br>503/753-9166 | | | | | X | X | X | | |

*This OSU service will no longer be offered after the 1985/86 testing season.

## TISSUE NUTRIENT ANALYSES*

5. Oregon State University
   Soil Science Department
   Plant Analysis Laboratory
   Corvallis, OR 97331
   Contact:
   Dean Hanson 503/754-2441

6. Oregon State University
   Horticulture Department
   Corvallis, OR 97331
   Contact:
   Jim Wernz 503/754-3695

7. Chinook Research Laboratories
   333 N. Santiam Hwy. Lebanon, OR
   97355 Contact:
   John Burnett 503/259-2488

8. Western Laboratories, Inc.
   P. 0. Box 400 Parma, ID
   83660 Contact:
   John Taberna 208/722-6564

9. Soil and Plant Laboratory, Inc.
   P. 0. Box 1648 Bellevue, WA 98009
   Contact:
   Dirk Muntean 206/746-6665

* Note: This is a partial list of PNW and Intermountain analytical laboratories. Nearly every landgrant university will have one or more labs. Readers are encouraged to learn of other facilities in their respective states.

## SAMPLING AND SHIPPING

A full battery of vigor tests will require 120-150 seedlings. Samples should be representative of the lot as a whole. Depending on the time of year and reason for the test, seedlings can be sampled directly from the nursery bed, the grading line, cold storage or planting site. More than one sample is recommended for seedling lots that occupy large areas in the nursery. The user's judgment is important in determining what constitutes a representative sample.

Seedling samples should be promptly refrigerated (between 2° and 10° C) and transported to the test location. Samples taken from storage should also be kept cool. Warm temperatures for prolonged periods can reduce seedling vigor. Seedlings can be shipped in heavy-duty, wax-coated cardboard boxes or ice chests via a commercial bus, the United Parcel Service, or personal delivery. Since there is always the likelihood of transport problems (such as a seedling lot sitting in a warm bus depot overnight), it is advisable to notify someone at the test facility that you are sending seedlings and when to expect them. Same day or overnight delivery is preferred.

As a final note, seedling shipments should be scheduled so that weekend deliveries are avoided (unless prior arrangements have been made). Maintaining a close working relationship with the test facility will pay off in more prompt and reliable service and results.

## CONCLUSION

The potential benefit of seedling quality testing is very high relative to the cost. Although enough data exist to demonstrate the usefulness of these tests, there is still a need for more complete information about the interaction between seedling quality attributes and site-specific conditions. For example, which seedling traits are most important on droughty sites?, or on moist coastal sites where competing vegetation is the limiting factor? Aside from the seedling aspect, it is also important that a forester be able to determine or predict accurately the growth limiting factors on a site.

Acquiring new knowledge about seedling quality testing will require a close working relationship between the nursery manager, forester and vigor test personnel. As more experiments and field trials confirm and fine-tune the usefulness of these tests, the more the procedure will become a routine part of regeneration practices. On an historical note, when Wakely (1954) proposed morphological grades for culling seedlings, there was undoubtedly reluctance on the part of many nursery managers to discard seedlings simply because they were small. Now morphological grading is a routine practice.

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## REFERENCES

Burdett, A. N. 1979. A non-destructive method for measuring the volume of intact plant parts. Can. J. For. Res. 9:120-122.

Duryea, M. L. 1985. Evaluating seedling quality: Importance to reforestation. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 1-4.

Faulconer, J. R. and B. E. Thompson. 1985. Benefits of knowing seedling quality. In Proc.: West. and Intmtn. Nurserymen's Assoc. meeting, August 14-16, 1984, U.S. For. Serv. Gen. Tech. Report INT-185, June 1985, pp. 84-87.

Glerum, C. 1985. Frost-hardiness of coniferous seedlings: Principles and applications. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 107-123.

Joly, R. J. 1985. Techniques for determining seedling water status and their effectiveness in assessing stress. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 17-28.

Landis, T. K. 1985. Mineral nutrition as an index of seedling quality. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 29-48.

Lavender, D. P. 1985. Bud dormancy. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 7-16.

McCreary, D. D., and M. L. Duryea. 1985. OSU vigor test: Principles, procedures, and predictive ability. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 85-92.

Ritchie, **G. A.** 1985. Root growth potential: Principles procedures and predictive ability. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 98-105.

Ritchie, G. A. 1984. Assessing seedling quality. In: Forest Nursery Manual: Production of bareroot seedlings (M. L. Duryea and T. D. Landis, eds.), Martinus Nijhoff/Dr. W. Junk Publishers, for For. Res. Lab., Oregon State Univ., Corvallis, OR. pp. 243-259.

Thompson, B. E. 1985. Seedling morphological evaluation -- What you can tell by looking. In Proc.: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests (M. L. Duryea, ed.). Workshop held Oct. 16-18, 1984. Forest Res. Lab., Oregon State Univ., Corvallis, OR. pp. 59-71.

Wakeley, P. C. 1951. Planting the southern pines. USDA For. Serv., S.E. For. Exp. Stn. Occ. Paper 122. 579 p.