BENEFITS OF KNOWING SEEDLING QUALITY

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ABSTRACT: Standards for assessing forest seedling quality are shifting from traditional morphological characteristics to internal, physiological condition. Several tests for evaluating seedling physiological condition are described, and potential applications are suggested. Example test results from 1982 through 1984 are presented for coastal Douglas-fir seedlings; their implications for the nursery manager are discussed.

INTRODUCTION

Standards of nursery seedling quality have long been an important issue among nursery managers and regeneration foresters. Traditionally, quality standards have been based on external morphological characteristics such as height, diameter, and root mass. More recently, attention has shifted to aspects of internal physiological vigor as a basis for rating seedlings. Tests for evaluating several attributes of seedling vigor have been developed which can provide valuable information regarding the physiological status of nursery stock. Although these tests are well documented in the literature, they have yet to become standard practice for most of the industry. This is probably due to the fact that most nursery managers and foresters have neither the time nor the facilities required for conducting them in a reliable manner. Recently, however, laboratories have been established in the Northwest that will perform seedling quality testing for interested parties. Because of the increasing availability of such services, now is a good time to evaluate some of the practical benefits of the various tests.

There are many good reasons to have reliable physiological information on nursery seedlings at every stage of the production cycle. This paper will be restricted to a brief discussion of the tests currently utilized by International Paper Company and a few of the more critical applications where they can be of particular value. To illustrate these applications, some example results from our testing service **will** be presented. It should be understood that the data were not collected as part of a formally designed research study, but are instead a summary of many tests performed for ourselves and other companies and agencies during the 1982-83 and 1983-84 lifting/planting seasons. Results will be restricted to those from Douglas-fir seedlings from seed zones west of the Cascades and grown at west-side nurseries in Oregon and Washington. The general principles, however, are applicable to nursery production in any region.

THE TESTS

There are five components to International Paper's testing program. They include an assessment of 1) root-growth potential (RGP), 2) frost-hardiness, 3) dormancy release, 4) greenhouse survival, and 5) standard morphological measurements. Briefly, they are conducted as follows:

Root Growth Potential:

Sample seedlings are potted in a rooting medium and placed in a greenhouse where optimum growing conditions (warm temperatures, long photoperiod, frequent irrigation) are maintained. This is similar to the original method developed by Stone (1955). After a specified period (usually 28 days), the seedlings are carefully unpotted and new root growth is evaluated using a quantitative index similar to that suggested by Burdett (1979).

RGP is affected by both the overall vigor of the seedlings and recent handling practices, such as duration of cold-storage. The seasonal development of RGP has been linked to the dormancy cycle so that, in general, it increases with the number of chilling hours received. However, because chilling requirement varies with seed origin, and since accumulated chilling hours can be nullified by unseasonably warm temperatures (Nienstadt 1967, Krugman and Stone 1966), RGP is difficult to predict during the lifting season. Because of this, testing RGP is most useful at the time of lifting and at planting time. With this information, one may assess the appropriateness of the lifting date and the effects of cold storage on the RGP of seedlings lifted on that particular date. The value of determining this aspect of seedling quality is underscored by the fact that several investigators have established a positive correlation between laboratory RGP and subsequent field performance for several coniferous species (Stone 1955, Stone and others 1961, Jenkinson 1976-77, Burdett 1979).

Frost-Hardiness:

Sample seedlings are frozen to three or four temperatures in a programmable freezing chamber, after which they are placed in the greenhouse. After five days, injury is assessed visually using a method in which

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damage to the stem (cambium), buds, and needles is rated separately in order to arrive at an overall rating for each seedling. This whole-seedling method is superior to evaluation methods which consider only a portion of seedling tissues. It also makes it possible to assess the differential development of frost-hardiness within the various seedling tissues during the hardening and dehardening processes. After injury is assessed, a curve is constructed which reflects the amount of mortality at each temperature; the LT(50) (temperature resulting in 50% mortality) is then determined from this curve.

Dormancy Release; Greenhouse Survival:

Sample seedlings are potted and placed in a greenhouse under optimum growing conditions. After 28 days, percent bud-break and survival are determined. Dormancy release is a function of chilling hours received and is thus linked to RGP. A high percentage of burst buds indicates that the chilling requirement has been fulfilled and the seedlings are at or past the optimum lifting window. Poor greenhouse survival is typical of a seedling lot of seriously sub-standard vigor. In such cases, this test may be the most conclusive indicator of seedling quality.

Morphological Evaluation:

Although physiological vigor is the major focus of the testing program, size and balance are still important descriptive attributes of seedling quality. Measurements are made of height, diameter, terminal bud height, and shoot/root dry weight ratio. Most of these measurements will be familiar to nursery managers and need no further explanation. For coastal Douglas-fir, mid-winter terminal bud height has been positively correlated with primordia (needle) number on the following spring's terminal flush (Thompson, unpublished report 1984). Presumably, then, given the same physiological status, balanced seedlings with larger buds will have a greater growth potential during the first year on the plantation.

CULTURAL PRACTICES AND SEEDLING QUALITY

For the nursery manager, one of the most valuable applications of seedling testing is to assess the effects of nursery cultural regimes on seedling physiology. Nursery practices can have profound impacts on both overall seedling vigor as expressed by frost-hardiness and RGP and on the rate and degree of dormancy development. For lots tested at International Paper's lab, nursery of origin had greater influence on test results than did seed source. The variation between nurseries did not follow any consistent latitudinal or elevational gradient based on nursery location. Evidently, nursery practices are able to mask any variation due to seed source or nursery location. This is illustrated by the frost-hardiness development curves for seedlings of two Douglas-fir seed zones, each of which were grown at two separate west-side nurseries (fig. 1). In general, seedlings from Nursery B hardened four weeks earlier than those at Nursery A. Besides suggesting that the potential for frost damage was greater at Nursery A, this delay in hardening raises the concern about proper development of dormancy, as we shall see in the next section.

Most nursery practices have been developed to tailor the morphological characteristics of conifer seedlings. These include sowing density, fertilizer schedules, root pruning, and top mowing, to mention a few. Nursery managers vary these practices in order to attain certain morphological targets. Other practices, such as late-summer water stressing and wrenching, are meant to trigger the dormancy induction process. The effect of most of these practices on physiological quality at lifting remains largely uninvestigated. Frost-hardiness, RGP, and dormancy development are all subject to cultural influence, particularly by such practices as top mowing and root pruning. These activities may significantly alter the hormonal balance within seedlings (Lavender and Hermann 1970).

International Paper has utilized seedling testing as a basic component of nursery research for several years. It has proven to be a very valuable tool for gauging the effect of several nursery practices on seedling quality. A thorough understanding of the physiological implications of any cultural

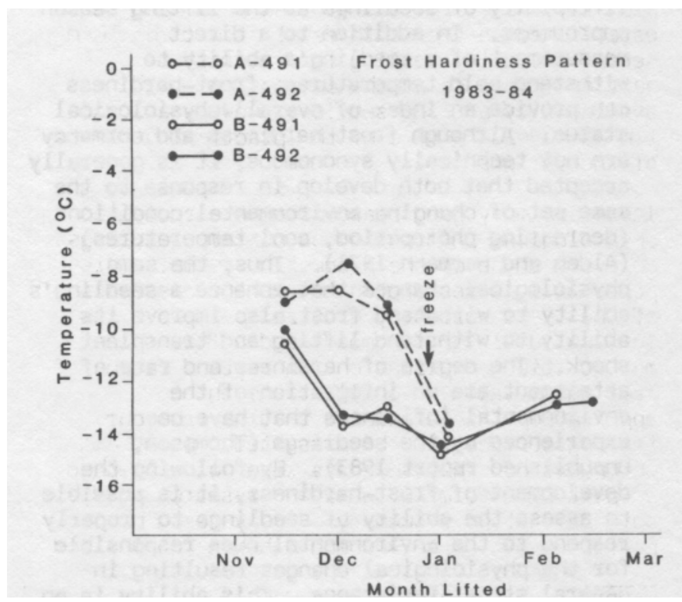


Figure 1.--Frost-hardiness pattern of two Douglas-fir seed zones (491, 492) each grown at two separate west-side nurseries (A, B). Arrow indicates approximate timing of a severe freeze in late December 1983. Data points are LT50's, or the temperature at which 50% of the seedlings in the lot did not survive the test.

technique is vital to the consistent production of quality stock.

COLD-HARDENING, DORMANCY, AND LIFTING

in addition to evaluation of cultural practices, seedling testing, especially for frost-hardiness, can be very useful as a guide for nursery managers during the fall hardening period and lifting season. Because the frost-hardiness test is one of the quickest to perform, it can be used to track the physiological changes occurring in seedlings during the hardening period. one direct application of the results is to determine the need for frost protection.

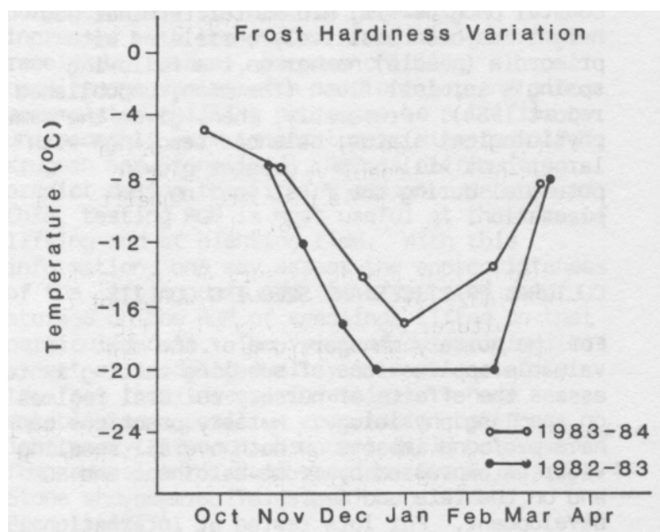
The potential for damage to seedlings by early fall frosts prior to adequate hardening is well recognized. Several methods for preventing or minimizing such damage have been devised, the most common being overhead sprinkling. However, there often is uncertainty as to the extent to which seedlings have hardened at any point in time, making it difficult to know when frost protection is truly warranted. Tracking the development of frost-hardiness during the fall helps to eliminate the guesswork. As the seedlings harden, appropriate adjustments may be made to temperature alarms and automatic sprinkler systems, and thus avoid unnecessary frost protection (and the risk of mechanical ice damage).

Another valuable application of frost-hardiness testing is to assess the general vigor and liftability of seedlings as the lifting season approaches. In addition to a direct measurement of a seedling's ability to withstand cold temperatures, frost-hardiness can provide an index of overall physiological status. Although frost-hardiness and dormancy are not technically synonymous, it is generally accepted that both develop in response to the same set of changing environmental conditions (decreasing photoperiod, cool temperatures) (Alden and Hermann 1971). Thus, the same physiological changes that enhance a seedling's ability to withstand frost also improve its ability to withstand lifting and transplant shock. The degree of hardiness and rate of attainment are an integration of the environmental influences that have been experienced by the seedlings (Thompson, unpublished report 1983). By following the development of frost-hardiness, it is possible to assess the ability of seedlings to properly respond to the environmental cues responsible for the physiological changes resulting in general stress resistance. This ability is an indication of the overall vigor or health of the seedlings.

We have already seen that nursery cultural practices can alter or interfere with the ability of seedlings to properly respond to environmental cues. Data from the two previous testing seasons indicate that seedlings may also exhibit annual variation in the rate and degree of frost-hardening.

During the fall and winter of 1982-83 coastal Douglas-fir seedlings displayed the typical pattern of gradually increasing hardiness in November and December, reaching maximum hardiness in January, followed by a rather rapid de-hardening during late February and March. When this trend is compared to the same type of test-generated curve for the following year (1983-84) it is apparent that, although the overall pattern is *very* similar, seedlings from the second year averaged 3-5° C less hardy at any given point between November and March (fig. 2). Another way to look at this is to say seedlings from 1983-84 were two to three weeks behind those of the previous year.

Because this variation was observed at all west-side nurseries tested, it seems likely that some environmental factor in effect across the entire region was responsible. The probable cause is annual variation in temperature patterns and the amount of chilling hours experienced by the seedlings during the early stages of cold-hardening and dormancy induction. In any case, the implications of decreased or delayed cold-hardening with respect to lifting date should be examined. In general, seedlings lifted during the early part of the 1983-84 lifting season were more likely to suffer handling damage and transplant shock than those lifted at the same time the previous year. Because frost-hardiness testing can identify such annual variation in hardening trends by November, the information can be used when scheduling lifting operations. During a year such as 1983-84, early lifting should be delayed if possible, or prioritized so that the hardiest lots are lifted first.



Month Lifted

Figure 2.--Average frost-hardiness variation of coastal Douglas-fir seedlings grown in west-side nurseries in two successive years. Data points are LT50's, or the temperature at which 50% of the seedlings did not survive the test.

CONCLUSION

Seedling quality testing has many valuable applications for the nursery manager. It can assist in the production of quality stock and help to ensure that quality is not compromised during lifting operations. Eventually, standard curves illustrating the seasonal development of root-growth potential and frost-hardiness can be developed for the many provenances of the species utilized in regeneration programs. Such curves can be used as guides for nursery managers and foresters, enabling them to fine-tune lifting and planting schedules to most suitably match the condition of the seedlings.

Of course, the ultimate test of seedling quality is field performance. Many factors influence the performance of seedlings after they leave the nursery. These include post-lifting storage conditions, handling and planting techniques, planting site conditions, and post-planting environmental factors such as weather, vegetative competition, and animal damage. Some or all of these influences combine to make predictions of field performance based on seedling test results difficult. This difficulty does not detract from the value of such tests. On the contrary, the potential adversity confronting seedlings during and after planting make it more critical for both nursery managers and foresters to be confident in the quality of planting stock as it leaves the nursery. With this baseline information, the forester may then wish to conduct tests to evaluate the effects of post-lifting storage and handling on seedling quality. By ensuring that seedling quality is enhanced, or at least maintained, through all phases of reforestation programs, the success of such programs will be improved.

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