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OSU VIGOR TEST: PRINCIPLES,

PROCEDURES, AND PREDICTIVE ABILITY

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Duryea, M. L. (ed.). 1985. Proceedings: Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. Workshop held October 16-18, 1984. Forest Research Laboratory, Oregon State University, Corvallis. ISBN 0-87437.000-0

ABSTRACT--A vigor test has been developed at Oregon State University to assess the quality of planting stock. The basic premise is that seedlings are exposed to considerable stress during outplanting and first-year establishment and that these stresses can be lethal to weaker, damaged, or less vigorous lots. In the OSU vigor test, seedlings are exposed to artificial stress and then placed in a controlled environment and monitored. If they are unaffected by this treatment and survive and grow well after potting, they are concluded to be vigorous and healthy and to have a high potential for field survival and growth. If. however, they die, they are judged to be of poor quality with a low potential for field performance. Preliminary results from two recent studies indicate that there is a highly significant correlation between field performance and growth-room survival.

7.1 INTRODUCTION

7.1.1 Factors Causing Seedling Injury

A primary goal of any forest nursery or greenhouse operation is to raise healthy, vigorous seedlings for outplanting. To the outsider. this may seem an easy task. Yet experience over the past several decades has indicated that many circumstances can contribute to seedling injury and cause a reduction in the overall quality of planting stock. Unseasonal weather patterns or improper nursery or greenhouse cultural practices can interfere with the natural growth and dormancy sequences and make seedlings susceptible to frost or other environmental stresses after they are outplanted. For example, too much irrigation late in the summer can cause prolonged growth, late bud formation, and insufficient dormancy at the time of lifting (Lavender 1984). Similarly, insufficient dormancy and lack of frost hardiness can result from imposing the wrong photoperiod or temperature regimes on greenhouse stock (Lavender et al. 1968, McCreary et al. 1978). Poor culturing practices can also lead to conditions favoring insect and disease attacks.

Seedlings can also be significantly damaged by careless lifting and handling practices (Burdett and Simpson 1984). Lifting seedlings from wet, heavy soils can cause root stripping and the loss of most fine roots. Piling field containers too high or overstuffing seedlings in storage boxes can physically injure seedlings. And root desiccation during the lifting and processing of bareroot seedlings can result in permanent damage to root systems (Coutts 1981).

Improper storage conditions are another potential source of injury (Edgren 1984). Malfunctions of coolers can result in warm temperatures that greatly enhance the development of harmful molds (Hopkins 1975) and induce physiological changes causing premature growth. Excessively cold temperatures, on the other hand, can severely damage or kill seedlings (McCreary 1984). Furthermore, insufficient initial moisture or improperly sealed storage containers can cause roots to dry out.

There are many more factors that can reduce seedling quality. And although knowledge of the physiological requirements of seedlings and the conditions that can injure them has greatly expanded in the last 20 years. many other contributing factors and interactions are not yet completely understood.

Sometimes injury to seedlings is obvious. If picking up seedlings from a recently opened storage container reveals that most of the needles are gray and immediately drop off, then the seedlings have obviously been severely damaged by mold. Often, however, seedling injury goes undetected because there are no outward visual symptoms. A root system that has dried out and is then rewatered may appear much like one from a properly treated seedling. Unless there is a reason to suspect injury, seedlings that appear normal and healthy are usually planted.

7.1.2 Consequences of Planting Damaged Seedlings

The consequences of planting dead or damaged seedlings can be very costly. Plantation failures caused by stock of poor quality result not only in the additional expenses of procuring and planting seedlings later, but often in much higher costs of site preparation as well. On sites where vegetative competition is a problem, a delay in planting can greatly modify the field environment and require expensive silvicultural prescriptions that might otherwise have been unnecessary (Newton and White 1983). Recent court rulings limiting the use of herbicides could increase these costs even more (Belloni 1983).

Even if seedlings of poor quality survive, their growth during the first few years may be greatly reduced. Such a reduction during the establishment period can result in an extended rotation age and thus reduce the present net worth of the land (Brodie and Tedder 1982).

7.1.3 The Need to Assess Seedling Quality

Being able to assess the quality of planting stock before it is outplanted would allow injured seedlings with a poor chance of survival or acceptable growth to be identified. One method developed and used at Oregon State University (OSU) for this purpose is the seedling vigor or stress testing technique. The object of this paper is to describe how this technique was developed, explain the principles on which it is based and the procedures currently used, and finally, to report on how well vigor testing predicts field survival and growth.

7.2 DEVELOPMENT OF VIGOR TESTING PROCEDURE

The current vigor testing procedure was largely an outgrowth of research conducted in the mid 1960's to quantify the tolerance of Douglas-fir seedlings to root desiccation. At that time. Hermann (1967) published a paper on the seasonal variation in sensitivity of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] seedlings to root exposure. In his studies. Hermann found there was a marked periodicity in the tolerance of seedlings to such exposure. with seedlings lifted in January exhibiting the greatest tolerance and those lifted in November and March (outside of what we now consider the optimal lifting windows) showing a much lower tolerance. This research was instrumental not only in helping to understand the dormancy cycle in Douglas-fir seedlings, but also in determining how to time lifting operations to coincide with the greatest resistance of seedlings to the shocks associated with lifting and planting.

Hermann (1967) also found that both survival and growth of outplanted seedlings were generally well correlated with those of seedlings placed in a growth room after root exposure. However, he noted that in the growth room mortality was concentrated within a month after planting, whereas in the field it was often not observed until late in the growing season. Root exposure also tended to accentuate differences in the survival of potted seedlings. Seedlings potted without root exposure generally had less variation in survival and growth than similar seedlings whose roots were exposed before potting.

From this research evolved the idea that the quality of seedlings could be assessed by exposing their roots and then observing them in a growth room. Because observed mortality generally occurs within 1 or 2 months in the growth room, such observation could be used to determine the vigor of planting stock and predict subsequent field performance (Hermann and Lavender 1979).

7.3 UNDERLYING PRINCIPLES AND OBJECTIVES OF VIGOR TESTING

In normal lifting, handling, storing, and planting operations, seedlings undergo considerable stress. Bareroot seedlings are physically removed from an environment where they have grown since the seeds were sown, and their roots, which have been in contact with the soil since germination, are suddenly exposed. In the lifting of bareroot seedlings. many fine roots are often torn off. The seedlings are then stored for varying periods and then outplanted on sites where conditions are much more adverse than they were in the nursery or greenhouse. In order to survive and grow, these seedlings must adapt quickly to their new environment. They must initiate new root growth, take up nutrients. and be able to maintain an adequate moisture status. Vigorous healthy seedlings can normally withstand the above-mentioned stresses and begin to initiate the physiological processes required for survival and growth. Previously damaged or weakened seedlings, however, may have a much harder time adapting and consequently may grow very slowly or even die.

The basic assumption of vigor testing is that the normal stresses encountered during planting and first-year establishment can be roughly simulated by exposing seedlings to artificial stress. After such stress is applied, the seedlings are placed in a controlled environment and monitored. If they are unaffected by the artificial stress and survive and grow well after potting, they are considered to be vigorous, high-quality stock and to have a high potential for field survival and growth. If, however, they are adversely affected and a high percentage die. they are considered to be of poor quality and to have a low potential for field survival and growth. Vigor testing is an integrative approach to evaluating quality because previous damage to a variety of physiological systems within seedlings will presumably be expressed by poor survival or delayed bud burst.

7.4 PROCEDURES OF VIGOR TESTING

7.4.1 Sampling from Seedling Populations

The object of any quality assessment of seedlings is to predict quality of a population on the basis of measurements from a sample of seedlings. Unless the sample is representative of the lot, the prediction will be inaccurate. For example, if a cooler malfunctions and seedlings are accidentally frozen, it is likely that the seedlings in bags or boxes on the perimeter of the stacks would be exposed to colder temperatures than those in containers near the center and partially insulated by surrounding boxes or bags. It is also likely that those seedlings on the outside of the more exposed containers would be more severely frozen than those in the middle. In order to predict the quality of the lot in general, the sample to be evaluated should reflect all these varying levels of freezing. Either several samples should be evaluated separately--each reflecting a different suspected level of freezing--or a single sample comprising seedlings from each of these groups should be selected. The point is that the sample used for evaluation must reflect the condition of the lot in general in order for the prediction to be valid.

7.4.2 Time of Testing

Another important requirement if stress tests are to be used to predict field performance is that seedlings be evaluated close to the time they are outplanted. If seedlings are lifted and evaluated in December but not outplanted until March, the assessment may be invalid because the quality of the seedlings could change significantly during the 3 months of storage.

7.4.3 Seedling Transport. Stress Treatment. and Planting

For the OSU vigor test, we ask clients to send a representative sample of 60 seedlings from each lot to be evaluated. Seedlings are either delivered directly or shipped by bus or UPS. If they are shipped, we emphasize that seedlings should be sufficiently moist so that they will not dry out during transit. If it is necessary to transport seedlings long distances requiring more than one day for travel. we also suggest that packing boxes be insulated and that ice or blue ice be included. Once the seedlings arrive, we place them in a cold room until they are tested. We then randomly divide the seedlings into two groups of 30 and immediately plant one group into three pots of 10 seedlings each. These pots are then placed in a controlled environment (either greenhouse or growth room) where a 16-hour photoperiod and a constant temperature of 22°C are provided.

We stress the second group of 30 seedlings. First, all soil is washed from the root systems, which are then patted dry with absorbent towels. The seedlings (with their roots exposed) are then suspended in a hot, dry walk-in chamber for 15 minutes. The temperature in the chamber is maintained at 32°C and the relative humidity at 30%. After 15 minutes' exposure, most of the surface moisture is evaporated from the root systems. We then remove the seedlings and place them in water for 5 minutes. They are then planted in three pots of 10 seedlings each and set alongside the three pots of unstressed or control seedlings.

7.4.4 Evaluation of Seedlings

We evaluate all seedlings after 2 weeks. 1 month, and 2 months; then we discard them. On each assessment date we record the number of dead seedlings in each pot. A seedling is judged dead when all its needles have turned brown or are dry, brittle, and break when bent.

We also record the percentage of seedlings that has broken bud (needles emerging through bud scales from most advanced bud or visible new needles at least 2 mm in length for pines). For seedlings planted before January 1. this assessment is made 2 months after planting. For seedlings planted after January 1, the assessment is made after 1 month. This difference is necessary because seedlings lifted early generally have not received adequate chilling and thus take longer to break bud. Our predictions of seedling quality and potential for field performance are based on the 2-month survival percentages and the difference in bud activity between stressed and unstressed seedlings.

We also provide the 2-week and 1-month survival percentages to clients interested in early information about seedling response. Often the seedlings in a lot of extremely low vigor will begin dying within 2 weeks. We relay the information and indicate that the lot appears to be of poor quality.

Table 1 shows the guidelines for predicting the quality of tested lots on the basis of 2-month survival percentages and differences in bud activity between stressed and unstressed seedlings. If. for instance, survival within a lot were 93% for stressed seedlings after 2 months and 100% for unstressed seedlings, and there were little difference in bud burst between these two groups (e.g.. 79% vs. 87%). then we would judge this lot to be of excellent quality. If. on the other hand, a lot had the same survival percentages but a larger difference in bud burst between the two groups (e.g., 35% vs. 65%), then we would rate this lot slightly lower: "excellent to good." Thus, the larger difference in percentage of bud burst suggests a greater adverse effect of the drying treatment and indicates the lot is less vigorous than one in which bud activities were similar. In another case, if survival within a lot were 74% for stressed seedlings and 93% for unstressed ones, and the bud activities were similar, then we would call the lot "fair." If the differences in percentage of bud burst were greater than 25. however, we would call the lot "fair to poor." If survival were less than 60% in either group, we would judge the lot to be "poor."

TABLE 1. OSU VIGOR TEST--GUIDELINES FOR PREDICTING QUALITY OF TESTED LOTS.

% Growth room survival		Difference in % bud burst (unstressed minus stressed)	Predicted condition
Stressed	Unstressed		
91-100	91-100	neg. to 25	Excellent
91-100	91-100	26 to 100	Excellent-good
91-100	81-90	neg. to 100	Good
81-90	81-100	neg. to 25	Good
81-90	81-100	26 to 100	Good-fair
81-90	71-80	neg. to 100	Fair
71-80	71-100	neg. to 25	Fair
71-80	71-100	26 to 100	Fair-poor
60-70	60-100	neg. to 100	Fair-poor
<60	0-100	neg. to 100	Poor

7.5 PREDICTIVE ABILITY OF VIGOR TESTING

7.5.1 Previous Studies

Vigor testing is a relatively new technique. and most of the research on its ability to predict field survival and growth is still in progress. However, several papers have described the technique and compared results in the growth room to field performance.

Hermann (1967) presented data on field and growth-room survival of seedlings that were stressed by various periods of exposure. However, this research was not aimed at using growth-room survival to predict field performance. Hermann and Lavender (1979) described the methods used in the OSU vigor test. Lavender et al. (1980) correlated growth-room response to field survival of lots planted on a variety of sites in Oregon. They found that both survival and speed of bud burst of stressed seedlings in a controlled environment were related to seedling survival in the field. The correlations were not strong, however. When adjusted for lifting date and differences in planting sites, the partial correlation coefficient between growth-room survival of stressed seedlings and field survival was, though significant, only 0.52. The coefficient between field survival and speed of bud burst of stressed seedlings was 0.56. However, there was no significant correlation between field survival and either growth-room survival or bud burst of unstressed seedlings.

In 1982, the Nursery Technology Cooperative at OSU initiated a survey to determine how closely growth-room survival of lots submitted for testing that year correlated with actual field survival. Everyone who had had seedlings evaluated was requested to supply percentages of field survival. Altogether, we received information on 106 lots planted on a variety of sites. The correlation between field and growth-room survival was 0.63 for stressed seedlings and 0.44 for unstressed ones, both highly significant.

7.5.2 Problems with Previous Field Trials

One problem in determining the strength of the relationship between growth-room response and field survival is that, in most of the trials to date. the lots tested have been planted on different sites. Thus, one lot may have been planted on a relatively moderate site with favorable moisture conditions while another, tested at the same time, may have been planted on a much harsher site. The variability in site and planting conditions, if substantial. can interfere with accurate predictions of field performance because survival and growth can be affected more by the environment where seedlings are planted than by their condition at the time of planting.

Another difficulty with most previous attempts to correlate growth-room and field response has been the lack of variability in the quality of the lots tested as determined by growth-room survival. For instance, of the 106 lots evaluated in 1982, more than 80% had growth-room survival of 70% or higher, even after stress treatment. This lack of variation in stock quality means that many of the data points are clustered together, thus making it difficult to establish correlations.

7.5.3 Current Studies

In addition to its previously mentioned survey, in 1982 the Nursery Technology Cooperative also initiated a study to evaluate the vigor testing procedure more thoroughly and look at the ability of such tests to predict field performance. The approach differed from previous studies in that all seedling lots tested were planted on common, relatively uniform sites; thus, the variability in field survival as a result of site and planting differences could be minimized. We also tried to ensure a gradient in the quality of the seedlings lots by such methods as cutting the roots of the various lots to different lengths before the study began. The objective of these pretreatments was to create a range in the quality of tested seedlings from vigorous, healthy lots to extremely poor ones. Thirteen such lots were tested.

The main objective of this study was to evaluate the ability of the vigor testing procedure to predict potential, rather than actual. field performance. As mentioned, the actual field performance of any outplanted seedling will depend on the site where it grows as well as on planting technique. planting conditions, and yearly weather patterns. Minimizing the variability associated with these factors would enhance our ability to determine the relative field performance of lots of varying quality.

Clients had previously indicated that lots of poor quality, as identified by stress testing, may have fairly high survival, yet very poor initial growth. Therefore, first-year terminal growth was also recorded on surviving outplanted seedlings and correlated with growthroom survival.

Preliminary results from the study were analyzed and presented to Nursery Cooperative members. These results indicated that there was a highly significant correlation between field and growth-room survival of both stressed and unstressed seedlings. Furthermore. there were also highly significant correlations between terminal growth of surviving seedlings in the field and growth-room survival of both groups.

In the study. field outplantings were replicated on two sites: one on the OSU McDonald Forest near Corvallis and the other on the Glide Ranger District of the Umpqua National Forest in southern Oregon. the seed zone of the seedlings used. Overall year-end survival on the McDonald Forest site was 70%. while that on the Umpqua site was 57%. The correlations between field survival and 2-month growth-room survival of both stressed and non-stressed seedlings were highly significant for both sites. The correlations between field survival and 1-month growth-room survival were also highly significant and were only slightly smaller than those for 2 months. We did not find any significant correlation between bud burst in the growth room and either field survival or growth. These results are summarized in Tables 2 and 3.

We concluded from this study that potential field performance could be accurately predicted by measurements of growth-room survival of either stressed or non-stressed seedlings and that evaluation after 1 month was sufficient to give a good indication of seedling quality. We were surprised that the correlations were as high or higher for unstressed seedlings as for stressed ones, indicating that merely potting seedlings and recording their survival after 1 or 2 months could reliably predict field performance.

We decided to initiate a second study and include several new quality-reducing treatments including early lifting, cold storage, and root desiccation and to examine two Douglas-fir seed sources. In addition we wanted to look at the effect of storage on stress testing by evaluating all seedling lots both before and after a 2-month storage period.

Preliminary results from this study also indicated that, for the one site so far evaluated. the correlation between mid-summer field survival and growth-room survival at 8 weeks was again highly significant for both stressed and unstressed seedlings, but was higher for stressed ones. Furthermore, the linear regression of field survival on growth-room survival for stressed seedlings had a slope closer to 1.0 and passed nearer the origin than did a similar regression for unstressed ones (Fig. 1). Thus, there was nearly a oneto-one correspondence between field and growth-room survival for stressed seedlings. indicating that the field survival for a given lot and seed source was closely approximated by the corresponding growth-room survival for stressed seedlings.

7.6 LIMITATIONS OF VIGOR TESTING

7.6.1 Length of Evaluation Period

Current techniques for vigor testing, like those commonly used for assessing root growth capacity, require a long time before results are obtained. At present, we evaluate seedlings for 2 months, although, as mentioned previously, extremely poor lots may begin dying within 2 weeks. Studies in progress indicate that a 1-month evaluation may be adequate, but even this brief delay may be too lengthy for making decisions about whether to plant a lot suspected of being damaged. Furthermore, conducting a test several months before the seedlings are outplanted may result in inaccurate predictions because the condition of the seedlings may change during this period.

7.6.2 Variability in Field and Planting Conditions

A second limitation of vigor testing, as well as of any current method of evaluating seedling quality, is that predictions of actual field performance are difficult to make from test results because site and planting conditions greatly affect seedlings regardless of their quality. A lot identified as "good" may perform well on a moderate, protected site but poorly on a hot, dry site with shallow, rocky soils. Similarly, seasonal weather patterns can greatly affect field performance. Thus. during planting years with favorable weather. even lots identified as "poor" may survive and grow adequately. The important point is that until we refine our ability to identify the limiting factors associated with different

TABLE 2. RESULTS OF STRESS TESTS AND FIRST-YEAR FIELD PERFORMANCE.

	Growth-room survival (%)				Field survival (%)		Field height growth (cm)[a]
	Unstressed		Stressed		McDonald		McDonald
Quality treatment	1 mo	2 mo	1 mo	2 mo	Forest	Umpqua	Forest
Control (no treatment)	100	100	100	100	97	73	4.82
-8°C freezing for 2 hr	80	80	50	50	63	77	4.58
-10°C freezing for 2 hr	57	43	40	37	30	47	3.89
-12°C freezing for 2 hr	50	7	43	7	7	23	3.35
3-in. root prune	97	93	87	73	73	77	4.28
5-in. root prune	100	100	90	83	97	87	5.07
7-in. root prune	100	100	100	100	97	77	4.89
1-day hot storage (32°C)	100	100	100	100	100	80	4.06
2-day hot storage	80	70	87	73	93	63	3.21
4-day hot storage	23	13	30	20	17	0	2.03
Water submersion at 44°C for 15 min	100	100	100	100	97	73	4.80
Water submersion at 47°C for 15 min	90	90	100	97	100	47	4.28
Water submersion at 50°C for 15 min	30	20	40	20	41	17	2.76

[a] Field height measurements were not possible at the Umpqua site because of severe browsing.

TABLE 3. CORRELATION COEFFICIENTS FOR FIELD PERFORMANCE WITH GROWTH-ROOM SURVIVAL.

Field performance	Growth-room survival	Correlation coefficients
McDonald Forest survival	Unstressed (1 month)	r = 0.89
McDonald Forest survival	Unstressed (2 months)	r = 0.94
McDonald Forest survival	Stressed (1 month)	r = 0.94
McDonald Forest survival	Stressed (2 months)	r = 0.96
Umpqua survival	Unstressed (1 month)	r = 0.94
Umpqua survival	Unstressed (2 months)	r = 0.92
Umpqua survival	Stressed (1 month)	r = 0.76
Umpqua survival	Stressed (2 months)	r = 0.80
Field height	Unstressed (1 month)	r = 0.89
Field height	Unstressed (2 months)	r = 0.85
Field height	Stressed (1 month)	r = 0.71
Field height	Stressed (2 months)	r = 0.75

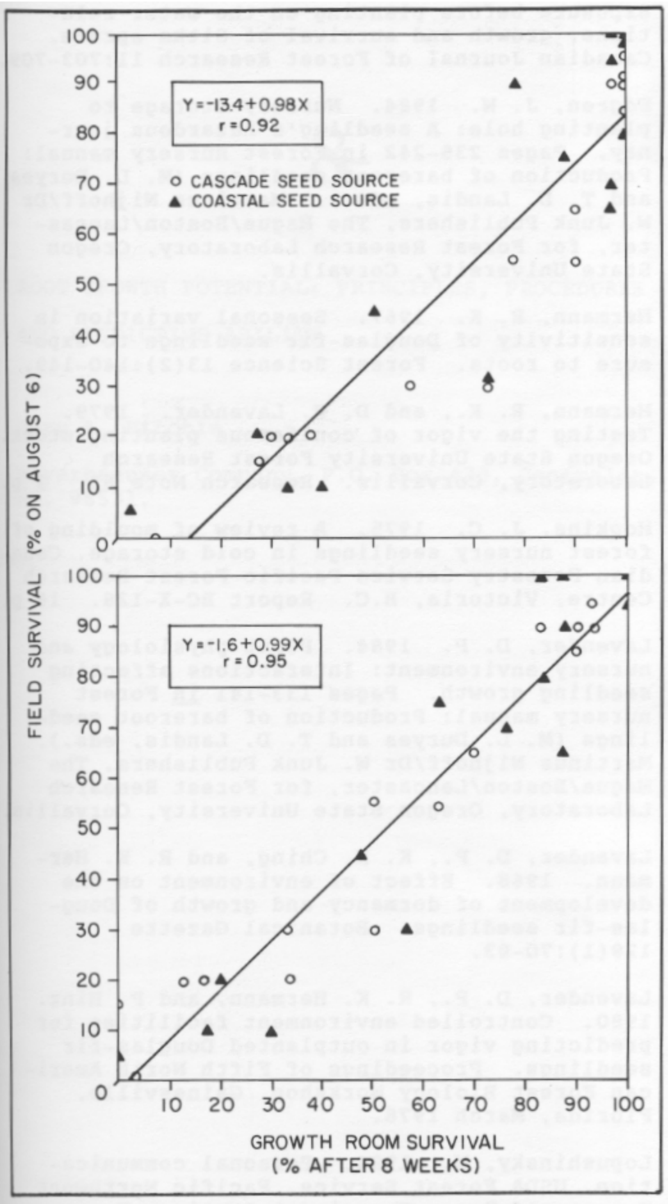

FIGURE 1. LINEAR REGRESSION OF FIELD SURVIVAL ON GROWTH-ROOM SURVIVAL FOR UNSTRESSED (TOP) AND STRESSED (BOTTOM) SEEDLINGS OF TWO SEED SOURCES.

sites and planting conditions, it will remain difficult to predict percentages of survival or growth increments--no matter how accurate the assessment procedure we develop.

7.6.3 Equipment Necessary for Vigor Testing

Another drawback of our current procedure is that it requires costly facilities including a controlled drying chamber and greenhouses or growth rooms. The critical factor in this procedure is that root drying during stressing be consistent and uniform. At OSU we have a large walk-in chamber in which constant temperature, humidity, and wind movement are maintained. Duplicating these conditions in small ovens would be difficult, and a change in any of them could substantially alter actual root drying. Building large chambers that provide the required conditions would generally be prohibitively expensive for small, local operations.

7.6.4 Other Factors Influencing Test Results

Finally, almost all of the research on stress testing has been done with Douglas-fir seedlings. Although we do test other species, we do not know if this procedure is equally effective for all of them. However, the Forestry Sciences Laboratory of the USDA Forest Service. Wenatchee. WA, has been using the OSU vigor test with a variety of east Cascade species including several species of pine (*Pinus* spp.). Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). and western larch (*Larix occidentalis* Nutt.): it reports generally good results (Lopushinsky 1984, pers. commun.). Such factors as the time of lifting and length of cold storage may influence the ability of stress testing to predict potential field performance. Some types of seedling injury may also be more easy to detect with this procedure than others. Needless to say, there is still work to be done in calibrating and fine tuning this assessment technique.

7.7 BENEFITS OF VIGOR TESTING

7.7.1 Ability to Predict Potential Field Performance

The preliminary results of two recent studies conducted by the Nursery Technology Cooperative have indicated that for Douglas-fir seedlings, stress testing gives a reliable indication of seedling quality and potential field performance. This is especially true for lots of poor quality that can be identified by low survival in the growth room. The ability to identify such lots gives foresters the opportunity to discard seedlings that have little chance for field survival or acceptable growth. The cost savings from not planting such seedlings have been previously discussed. Being able to assign a relative vigor index to different lots may also enable foresters to make better decisions about matching seedling lots to specific sites.

7.7.2 Determining Seedling Quality at the Nursery

Another important benefit of this technique is that it provides a means of determining whether seedlings shipped from the nursery are of good quality at the time of delivery. Plantation failures often lead to heated discussions about whether the stock was already damaged when it left the nursery or whether faulty storage conditions and improper planting practices resulted in poor field performance. If nurseries submit seedlings at the time of shipment and they perform well in the stress test, there is evidence that any problems associated with low survival or poor growth occurred after they left the nursery.

7.7.3 Identifying When Injury Occurs

Submitting repeated samples for stress testing can also help identify the stage in the culturing, lifting, handling, and planting process where problems resulting in low vigor occur. If repeated samples of a given lot are tested at each stage in this process (i.e.. at the time of lifting, after processing, during nursery storage, after transport, etc.) and suddenly vigor goes down as measured by stress testing, this information can be used to help determine when the damage occurred.

7.8 CONCLUSIONS

The current program of stress testing at OSU has been used operationally for 6 years. Approximately 1.500 seedling lots have been evaluated. During this period, the demand for this service has grown steadily, as evidenced by the number of samples submitted for testing. Responses from clients have indicated that this procedure is useful in assessing the quality of planting stock and predicting potential field performance. Recent studies by the OSU Nursery Technology Cooperative support this view. We have found consistent and highly significant correlations between field performance and growth-room survival. In particular, lots with low field survival have been successfully predicted by stress testing.

The major limitation of the current technique is the time involved in generating results. At present we evaluate seedlings for 2 months. although we can often determine if a seedling lot is of poor quality within a month or even 2 weeks. One of the major objectives of the current research effort at OSU is to determine if the time required for making an assessment of quality can be shortened so as to provide more timely information to clients.

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