EFFECTIVE USE OF WEATHER R VIABILITY TESTS FOR MO

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INTRODUCTION

Weather records are often used in the daily operations of tree nurseries. If long-term records are available for a particular nursery or can be obtained from the nearest available weather station, very comprehensive pictures of the expected mean daily weather conditions can be drawn up as an aid in planning nursery operations.

Parameters such as daily mean, minimum, and maximum air, ground level, and soil temperatures; growing-degree days; hardening-degree days; wind velocity, direction, and duration; precipitation; period from first to last frost; hours of sunshine; day length; and amount of snow cover are monitored at many weather stations across the country and are available to clients. These data can be summarized and depicted graphically. Local daily parameters can be recorded and plotted over the long-term averages. This information should then be used by nursery managers for planning daily, monthly, and annual operations. Unfortunately, this is not always done.

At the 1986 Prairie Federal-Provincial Nurserymen's Meeting in The Pas, Manitoba, we gave some results of tests being conducted on monitoring the viability of overwintering container stock (Dymock and Dendwick 1987). At that time, the use of daily weather records was also discussed in conjunction with the use of these tests. It was also pointed out that the weather records had the potential for use in a postmortem in the eventuality of a failure in the overwintering crop.

The effective use of these records is the theme of this discussion. The types of records available and how they can influence the decision-making process for nursery operations will be reviewed. Examples to be presented will relate to the research experiences from the Northern Forestry Centre (NoFC). These have the same potential for determining the success or failure of a crop in a production nursery regardless of whether it is a container or bare-root operation or both.

MATERIALS AND METHODS

Growing Schedules

Containerized seedlings of various conifer species have been reared in the greenhouses at NoFC each spring since May 1982 and for each successive year up to and including 1987 as part of the study on overwintering physiology of conifer seedlings. All seedlings have been reared using Schedule 2 for Frost Hardiness Zone 3 (Carlson 1983).

During 1982 and 1983, seedlings were grown under fluorescent lights that provided a minimum photosynthetic photon flux density (PPFD) of 57.6 micromoles per square metre per second of ($\mu mol \cdot m^{-2} \cdot s^{-1}$) photosynthetically active radiation (PAR) for up to 8 weeks during the early (greenhouse) rapid-growth period. The seedlings were then moved outdoors (to complete their later rapid growth) on June 24, 1982, and July 4, 1983. The rapid growth phase ended August 24 and August 31 of each year, respectively. On these dates, the hardening phase of Carlson (1983) was initiated and continued through to mid-October of each year as weather conditions permitted.

From 1984 onwards, seedlings were grown in the greenhouses under high pressure sodium vapor lamps (minimum PPFD = 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PAR for 14 weeks. They were then moved outdoors for hardening-off (Carlson 1983) under decreasing, ambient daylength and temperatures during mid to late August of each year as shown in Figure 1. The start of the vertical black lines, which indicate the daily range in temperatures, coincides with the date of moving seedlings outdoors to the shadeframes or cold frames. It has been recommended by Carlson (1983) that seedlings reared in Hardiness Zone 3 should not be moved outdoors to begin natural hardening any later than August 20. For our work it was usually possible to adhere to this schedule.

Test Sampling Schedules

Sampling was initiated in mid to late August and continued on a weekly or biweekly basis depending on the year, the species under study, and whether it was an initial or replicate sampling year. The dormancy tests used were the oscilloscope/square wave deformation method of Ferguson, Ryker, and Ballard (1975) for monitoring stem (cambial) activity and the root growth capacity test of Burdett (1979) for determining root activity. Rating and scoring were according to the methods outlined by Dymock and Dendwick (1987).

Cold hardiness-freezing tolerance tests were carried out on seedlings as described by Dymock and Dendwick (1987). A modified version of the conductivity test of Colombo, Webb, and Glerum (1984) was employed for rapid testing of both shoot and root cold-hardiness. Shoot and root damage and seedling survival were assessed after 4 weeks, according to the rating and scoring system outlined by Dymock and Dendwick (1987).

Environmental Parameter Monitoring

Historical weather records were obtained from the NoFC library in Edmonton, Alberta, for 1941-70. Microfiche copies of weather records for each year beginning with January 1983 were purchased from the Climate Control Centre, Atmospheric Environment Service (AES), Environment Canada, Downsview, Ontario. An excellent summary of Canadian climatic conditions and parameters by Hare and Thomas (1974) is very useful as a primary reference source.

Hourly temperature recordings in the NoFC shadeframes and cold frames were initiated during September 1983 using a 24-channel electro-mechanical Honeywell Recorder that was equipped with 24 copper-constantan thermocouples. Thermocouples were placed in the centres of container root plugs, at seedling bud level, in the air 1.8 m above the seedlings, and at ground level. Since January 1986 the temperature recordings have been made using a microprocessor-controlled Campbell Scientific CR-7 datalogger equipped with copper-constantan thermocouples placed as above.

All seedling trays were on wire racks in the shadeframes and cold frames. These were approximately 3 cm above the gravel bed of the shadeframes and cold frames. The shadeframes and cold frames were initially covered with shade cloth, which allowed for transmission of 50% of the available light. The shade cloth has since been replaced with Paraweb vinyl shading (55%) that allows snow to fall onto the seedlings.

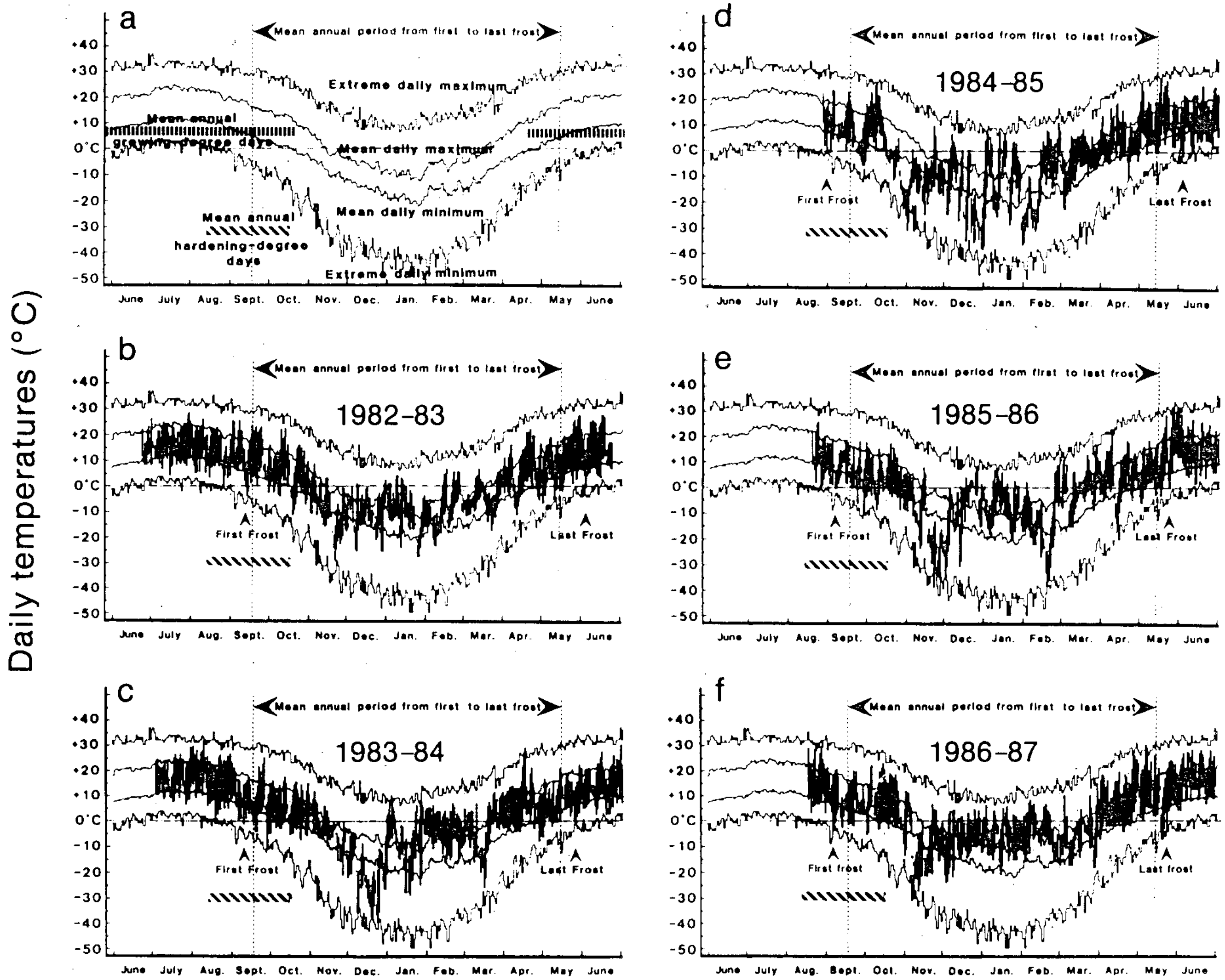

Figure 1. **Mean annual temperature data and temperature records for each experimental overwintering season.**

Details of the features of Figures 1a-f are outlined in the Materials and Methods and Results and Discussion sections.

RESULTS AND DISCUSSION

Weather Records and Recording Stations

First of all, what types of records are available? The Atmospheric Environment Service's Climate Control Centre provides very complete weather records for all weather stations that report to them. Up to the end of 1982, these were available free of charge and could be found in most libraries. Since January of 1983, the annual daily summaries from the Climate Control Centre system have become available on microfiche. These must be purchased in their entirety, but they are available at the NoFC library. More recently, detailed records have become available on computer tape. These can be purchased for individual weather stations for as long as these stations have been recording. These records will include all parameters that have been monitored at each weather station.

The Northern Forestry Centre is located at approximately 53°29'N latitude and 113°32'W longitude; altitude 700.1 m. The data shown in Figure 1a are the mean daily minimum and maximum temperatures for the 1941-70 period, at Edmonton Municipal Airport (53°34'N latitude, 113°31'W longitude; altitude 671 m) and the daily extremes for the Edmonton area recorded between 1885 and 1985. The Edmonton Municipal Airport weather station is closest to NoFC and has the longest recording history. We have also used weather records from the Ellerslie station (53°25'N latitude, 113°33'W longitude; altitude 694 m). This station was located on the University of Alberta Experimental Farm on Ellerslie Road, south of NoFC. Both stations are about the same distance from NoFC.

The Ellerslie station was located in a wide open area similar to the locale around NoFC, which is situated on the southern edge of the central University of Alberta farm on the south side of Edmonton. Environmental conditions at the two sites are very similar year-round. Where data are missing in NoFC site records, data from the Ellerslie station have been used.

Data collection at the Ellerslie station was discontinued December 31, 1986, but a new weather station at the University of Alberta Metabolic Centre (53°31'N latitude, 113°32'W longitude; altitude 668 m) began operations on January 1, 1987. This station is less than 1 km to the northeast of NoFC at the north edge of the University of Alberta Central Farm. The geographic and climatic conditions at this site are virtually identical to those at NoFC. Data from this station are now used to replace missing data from NoFC records.

Analysis of Weather Records

In Figure 1a the mean daily minimum and maximum temperatures for the period 1941 to 1970 and the extreme daily minimum and maximum temperatures for the 1885 to 1985 period have been plotted from June to June. This corresponds to the period during which all of the overwintering physiological studies have been carried out since 1982. Superimposed at the top of Figure 1a, between the black arrows and indicated by the heavy vertical dashed lines, is the mean annual period from first to last frost for 1941 to 1970. This period is 238 days long, from the 19th of September through to the 14th of May. This also indicates that the mean (normal) growing season is 127 days long for the Edmonton area proper.

Using this data, one can calculate the mean annual growing-degree days (see Figure 1a--heavy dashed horizontal line), which can be defined as the number of degrees per day that the daily mean temperature is above 5.5°C (Hare and Thomas 1974). Daily growing-degree days can be added to obtain the cumulative growing-degree days over the season. For the Edmonton area proper, the mean annual growing season extends from April 19 to October 18 (Fig. 1a), resulting in a mean value of 1330.3 growing-degree days over the season.

Using data in Figure 1a one can determine the expected periods of frost and time the movement of seedlings from the greenhouse to the outdoors. This minimizes the chance of frost damage both in the spring, for a spring-planted crop, or in late summer for a crop that is to be fall-planted or subsequently overwintered. As previously mentioned, the recommended last date for safely moving seedlings outdoors for the Edmonton area (Hardiness Zone 3) is the 20th of August (Carlson 1983).

One can also determine the cumulative hardening-degree days that may be available to ensure that a crop moved outdoors has sufficient exposure time to both declining natural daylength and dropping night temperatures. This is a strict requirement that must be met in order for the seedlings to harden-off adequately to ensure survival during overwintering. Hardening-degree days can be defined as the cumulative daily minimum difference between 10°C and the temperature at root level above 0°C (D'Aoust and Cameron 1982). For bare-root stock, this is measured at a depth of 15 cm. For container stock it is the root plug temperature. At NoFC the mean period that is used for calculating the cumulative hardening-degree days for container stock is from August 14 to October 15 (shown in Figures 1a-f as diagonally slashed horizontal lines). This yields a total of 295.8 cumulative hardening-degree days for container stock that is moved outdoors by August 14.

For each experimental season, comparing the daily temperature range with the long-term average allows for analysis of each season compared to the expected normals. By overlaying the recorded temperature ranges in black (Figs. 1b-f), it is apparent whether above average, normal, or below average temperatures prevailed at any given time or over the entire winter. It is then possible to diagnose the reasons for success or failure of a particular overwintered container crop that was stored outdoors under ambient conditions.

Occurrence of Frost and Freezing Periods

During any outdoor growing season or the hardening-off period, the incidence and severity of frost is expected to have varying effects on the crop, depending on the degree to which it has hardened. Frost is considered to occur when the minimum temperatures reach 0°C (Hare and Thomas 1974). A light frost can be defined as exposure to temperatures from 0 to -2.5°C; a hard frost can be defined as exposure to temperatures from -2.6 to -5.0°C; temperatures falling below -5.0°C can be defined as a severe frost in accordance with those definitions of Hare and Thomas (1974) and DeLucia and Smith (1987).

The duration of exposure to particular frost conditions will have a significant influence on seedling damage and viability. This is also true for the time of frost occurrence during the hardening period. Early and severe frost conditions are expected to be far more detrimental to a crop during hardening-off than would later, milder frosts (Kramer and Kozlowski 1979; Levitt 1980).

1982-83 Seasonal Weather Trends

The 1982-83 season (Fig. 1b) was the closest to the long-term averages of any of the experimental seasons. It did exhibit a short below-normal period in late November 1982 and several brief periods of moderately below normal daily temperatures later during the winter.

The seedlings, which were originally moved outdoors on June 24, experienced a total of 336.5 hardening-degree days between June 24 and October 24. This was 40.7 hardening-degree days (13.8%) above the expected cumulative mean of 295.8.

The first frost (light) occurred on September 12, 1983, which was 7 days earlier than normal. From September 12 to October 24 there were eight light, five hard, and three severe fall frosts. The last frost in the spring of 1983 occurred on June 3, 1983, 20 days later than normal (mean last spring frost date is May 14).

1983-84 Seasonal Weather Trends

Seedlings were moved outdoors on July 4 and were allowed to complete the rapid growth phase in the shadeframes. The 1983-84 season (Fig. 1c) was the second of five seasons in a row that experienced unusually cold (below normal) periods in late November and December. These were followed by unusually warm periods throughout mid-January, most of February, and into early March of 1984. A second brief below-normal period occurred in the middle of March, followed by a warm April.

These seedlings experienced a total of 270.5 hardening-degree days between July 10 and November 2, 1983, 25.3 hardening-degree days (8.6%) less than normal. The first fall frost (light) occurred on September 6, 1983, 13 days earlier than normal. This was followed intermittently by 16 light, 11 hard, and 3 severe fall frosts up to November 2. The last spring frost of 1984 fell on May 25, 1984, 11 days later than normal.

1984-85 Seasonal Weather Trends

The 1984-85 season (Fig. 1d) began on August 27, the date that seedlings were moved outdoors. It was climatically very severe, as has been previously reported by Dymock and Dendwick (1987). It began with a light, early frost on August 30, just 3 days after the seedlings were moved outdoors. This frost was 20 days earlier than normal and was followed by a below-normal period of light-to-severe frost and freezing conditions and snow during the third week of September. After this there was a severely cold (well below normal) period during late October, most of November, and into December.

The lateness in moving seedlings out of doors coupled with the incidence of frost resulted in the seedlings receiving only 172.5 hardening-degree days from August 27 to October 14. This was 123.3 hardening-degree days (41.7%) below the mean. During this time, seedlings were exposed to eight light, two hard, and two severe frosts, most of which occurred from September 22 to 29.

Above-normal conditions prevailed throughout most of January 1985, followed by an additional below-normal period in late January and early February. The remainder of the 1984-85 winter was very close to or slightly above normal. There were two more brief but severe freezing periods in late April and late May that came close to setting new records for extreme low temperatures on their respective dates. The last spring frost occurred on June 3, 1985, 20 days later than normal.

1985-86 Seasonal Weather Trends

The 1985-86 season (Fig. 1e) began on August 19 and was characterized by below-normal minimum temperatures in late August 1985, throughout most of September, and during the first week of October. The first fall frost (light) occurred on September 6, 1985, 13 days earlier than normal. Well below normal freezing temperatures prevailed throughout most of November and for a brief period in mid-December. Above-normal conditions then prevailed throughout the rest of December.

Seedlings had been moved outdoors on August 19, 1985. Between this date and October 21 they were exposed to 191.5 hardening-degree days, 104.3 fewer hardening-degree days (35.3%) than normal. Also during this time they were exposed to 17 light, 5 hard, and 4 severe frosts.

Daily temperatures in January 1986 were well above normal throughout much of the month. This was followed by more normal conditions in the first half of February, when a brief below-normal period of extreme cold occurred followed by a period of unusually warm conditions into early March of 1986. A brief period of near-record freezing conditions occurred during mid-April, followed by near normal conditions. The final spring frost occurred on May 23, 1986, 9 days later than normal.

1986-87 Seasonal Weather Trends

The 1986-87 season (Fig. 1f) began under favorable, very near normal conditions. Seedlings were moved out of doors on August 18, 1986. The first fall frost (light) occurred 13 days earlier than normal, however, on September 6. Although several brief periods of below-freezing minimum temperatures occurred throughout September and October, conditions were close to or slightly above normal for those 2 months. Much of November was characterized by very low temperatures, but these were not record lows. December highs were normal in the early part of the month. The lows were below normal during the second week, but the conditions moderated and were generally above normal throughout the rest of December 1986.

During the hardening-off period, the seedlings were exposed to 281.3 cumulative hardening-degree days between August 18 and November 4. This was only 14.5 hardening-degree days (4.9%) less than normal. They were also subjected to 14 light, 9 hard, and 4 severe frosts during this period.

Above-normal (or very near normal) conditions prevailed throughout much of January, February, March, and April of 1987. One brief below-normal period occurred in late March. From May 19 to 23, very severe below-normal conditions brought heavy snowfall followed by near-record low temperatures and high winds. During these 5 days, there were 3 days of hard frost and one severe frost. These conditions inflicted severe freezing damage to many trees and shrubs in the region, which were flushing early due to the warm spring conditions that had prevailed throughout April and most of May.

Seasonal Trends in Black Spruce Viability

Figures 2 and 3 illustrate the seasonal trends in black spruce stem (cambial) activity, as measured by the oscilloscope/square wave deformation method of Ferguson, Ryker, and Ballard (1975), root activity as measured by the root growth capacity test of Burdett (1979), and whole seedling cold hardiness (freezing tolerance) as determined by Dymock and Dendwick (1987). The scoring systems used in evaluating results were those reported by Dymock and Dendwick (1987) for each of the tests employed.

Figure 2 can be compared with weather trends in Figure 1c for the 1983-84 season, and Figure 3 can be

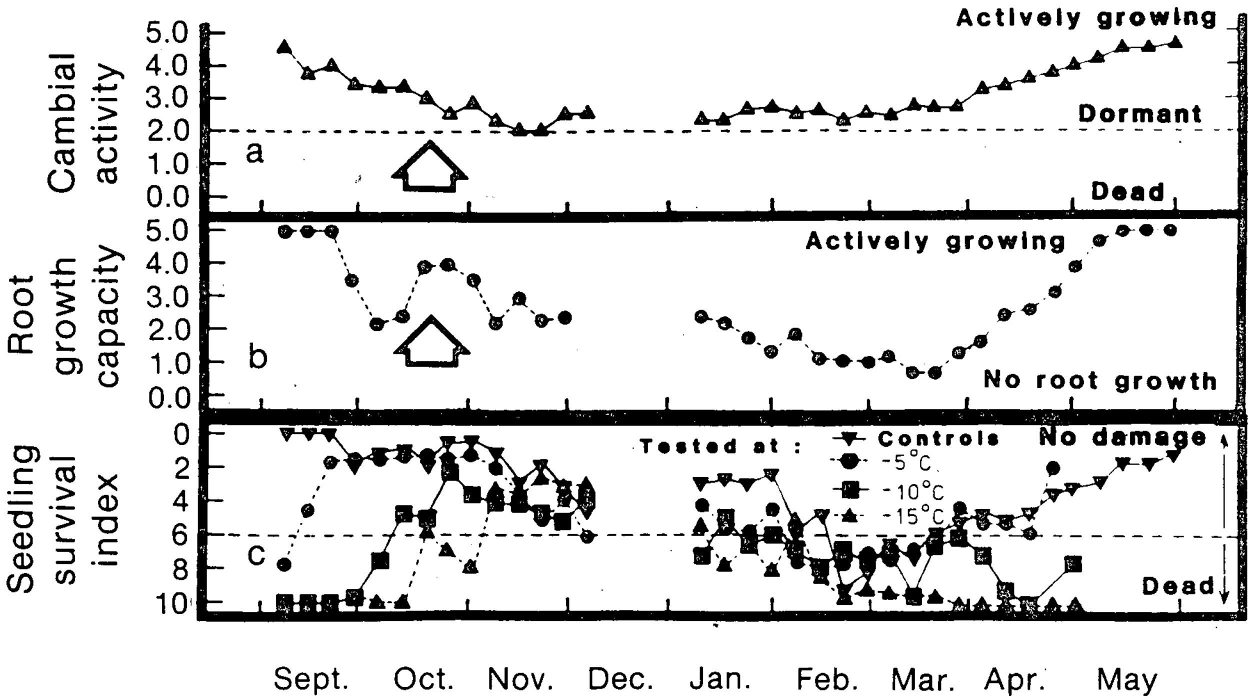

Figure 2. **Dormancy, freezing tolerance, and survival data for black spruce seedlings during the 1983-84 overwintering period.**

Cambial activity, root growth capacity, and seedling freezing tolerance-survival were determined according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, freezing tolerance and survival) or 20 (root growth capacity) seedlings.

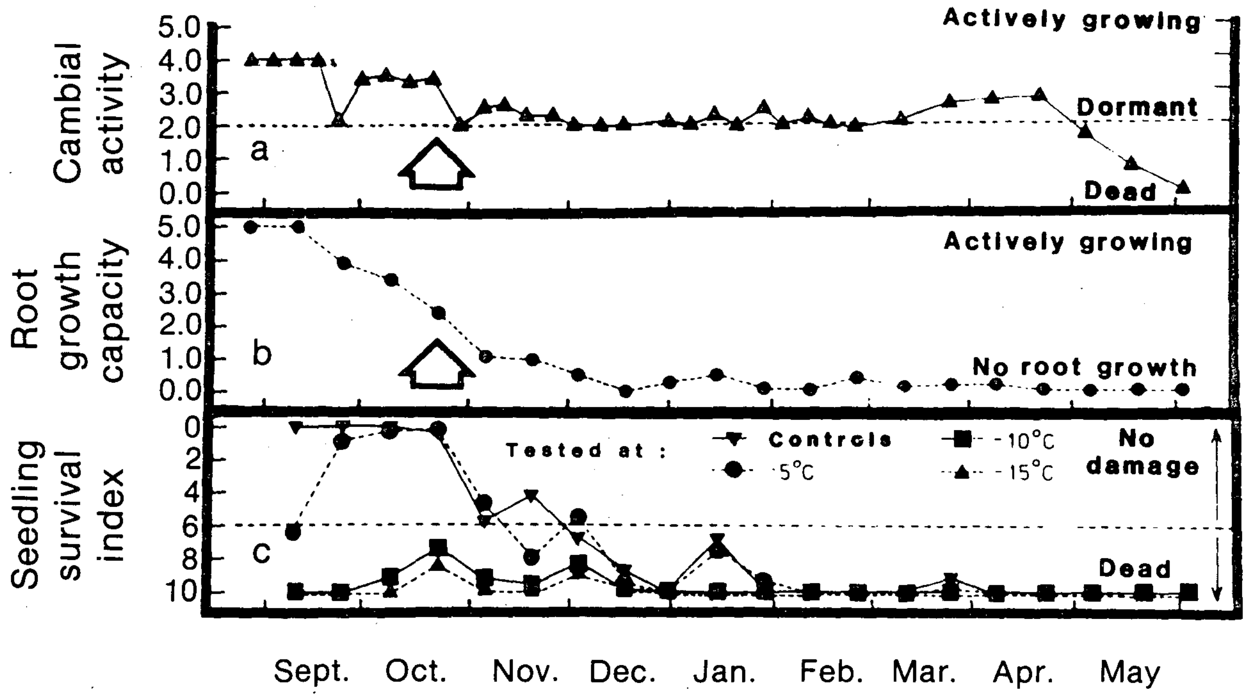

Figure 3. **Dormancy freezing tolerance, and survival data for black spruce seedlings during the 1984-85 overwintering period.**

Cambial activity, root growth capacity, and seedling freezing tolerance-survival were determined according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, freezing tolerance and survival) or 20 (root growth capacity) seedlings.

compared with weather trends in Figure 1d for the 1984-85 season.

Black spruce seedlings have been shown to develop cold hardiness much more slowly than other species such as white spruce and red pine when hardened-off under similar conditions (Dymock and Dendwick 1987; Edwards 1987). During the 1983-84 season, cambial activity (Fig. 2a) declined gradually as the number of hardening-degree days accumulated, even in the presence of light-to-hard frosts in the latter part of September and into October 1983. Root activity (Fig. 2b) tended to more closely follow root temperature trends and showed a major peak of root growth capacity in late October to early November that occurred during a period of normal day and night temperatures and frequent light-to-hard frosts. The total number of hardening-degree days came to within 8.6% of the normally expected values, suggesting that these seedlings had sufficient time to harden-off.

Further evidence for this can be seen in Figure 2c, where seedlings can be seen to have developed hardiness to each of the freezing test temperatures with time, reaching moderate hardiness to -15°C by late November.

During the 1984-85 season, however, a much different picture emerges for those black spruce seedlings (Figs. 1d and 3). Two early (light) frosts, within 6 days of moving the seedlings outdoors, caused visible shoot damage (data not shown). Eight consecutive days of light-to-severe frost from September 22 to 29 (Fig. 1d) were reflected in a sharp drop in stem cambial activity (Fig. 3a). Stem activity resumed as temperatures rose to normal in early October, but a second drop in stem activity parallels the sudden drop in temperatures and the increasing severity of freezing temperatures that occurred after October 15.

Root activity showed a steady decline during this time (Fig. 3b). Seedling freezing tolerance developed quickly to -5°C but achieved little beyond that, likely due to the numbers and severity of the frost events (Figs. 1d and 3c).

By October 14, total cumulative hardening-degree days reached only 172.5, which was 41.7% below normal. This can be partially accounted for by the lateness of moving the seedlings out of doors (August 27) and partially by the early frosts within 6 days. The second more-severe period during late September likely had a more-pronounced effect on arresting cold hardiness development after it had reached only -5°C.

Evidence reported by DeLucia and Smith (1987) for Engelmann spruce indicated that nightly air and soil temperatures down to -2.5°C would result in decreased rates of photosynthesis during the following day. If air and soil temperatures dropped to -5°C, substantial and irreversible reductions in photosynthesis would occur. As the black spruce seedlings that were used in this study were in containers outdoors, it is very likely that the shoots and roots were far more susceptible to extremes in temperature than would have been the case with bare-root stock.

Kramer and Kozlowski (1979), Levitt (1980), Tinus (1981), Carlson (1983), and Dymock and Dendwick (1987) have all reported on the increased sensitivity of roots to low temperatures. With this in mind and the data presented for the black spruce seedlings in the 1984-85 season, it is apparent that the roots (and to a lesser extent the shoots) suffered a series of severe, freezing events from which they were unable to recover in time to develop any further freezing tolerance beyond -5°C. The onset of temperatures that dropped below -15°C in the latter part of October was likely all that was needed to kill or fatally injure most of the black spruce seedlings at that point.

Comparison of Black and White Spruce Viability During 1984-85

Data shown in Figures 1d and 4 illustrate the differences in development and maintenance of cold hardiness and dormancy in black and white spruce trees during the 1984-85 overwintering season. White spruce stem cambial activity shuts down more quickly in response to the early frosts than does black spruce (Fig. 4a). This can also be observed with root activity (Fig. 4b). Both species were moved out of doors later than should normally have occurred, and both species were exposed to the same numbers of hardening-degree days and incidents of frost.

In spite of this, white spruce seedlings were able to develop moderate cold hardiness to -15°C for both their shoots and roots by late November, as shown in Figures 4c and d. The roots were slower to develop hardiness to the same degree as the shoots. They also lost their hardiness to -15°C much earlier in the spring than did the shoots. The conductivity test results that are expressed as an index of injury (Fig. 4d) suggest that the black spruce seedlings (shoots and roots) were still viable as late as April, but this was not supported by survival test results (Fig. 4c). White spruce results were comparable for both tests.

These results provide strong support for the concept that white spruce is a more cold-tolerant species and in order to ensure its survival is extent than black spruce. This appears to be particularly true for the overwintering container situation and is supported by more-recent results from our ongoing research[1].

SUMMARY AND CONCLUSIONS

It is readily apparent from the data presented here that there should and could be a far greater emphasis put on monitoring daily, weekly, monthly, and annual changes in environmental parameters in and around production nurseries. Any such program should include a comprehensive analysis of historical weather records from the nursery or the closest available weather stations. Once a comprehensive weather picture has been constructed for the nursery, the daily records will provide a clearer picture of the status of any particular crop in production.

An assessment of a crop success or failure can be carried out as we have done with our research program on monitoring overwintering viability of our containerized seedlings. Results of tests conducted can be compared to weather factors that may have influenced survival of the seedlings.

Simply monitoring daily air and soil temperatures will allow nursery staff to calculate parameters such as growing-degree days and hardening-degree days. This information alone will give a good indication of both seedling growth and seedling hardening potential based on solar heat input. Monitoring of other parameters such as soil moisture, seedling water status, and wind velocity, direction, and duration could provide sufficient basic information for regulating irrigation practices.

The judicious monitoring of environmental parameters in production tree nurseries or in tree improvement

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[1] I.J. Dymock, unpublished data.

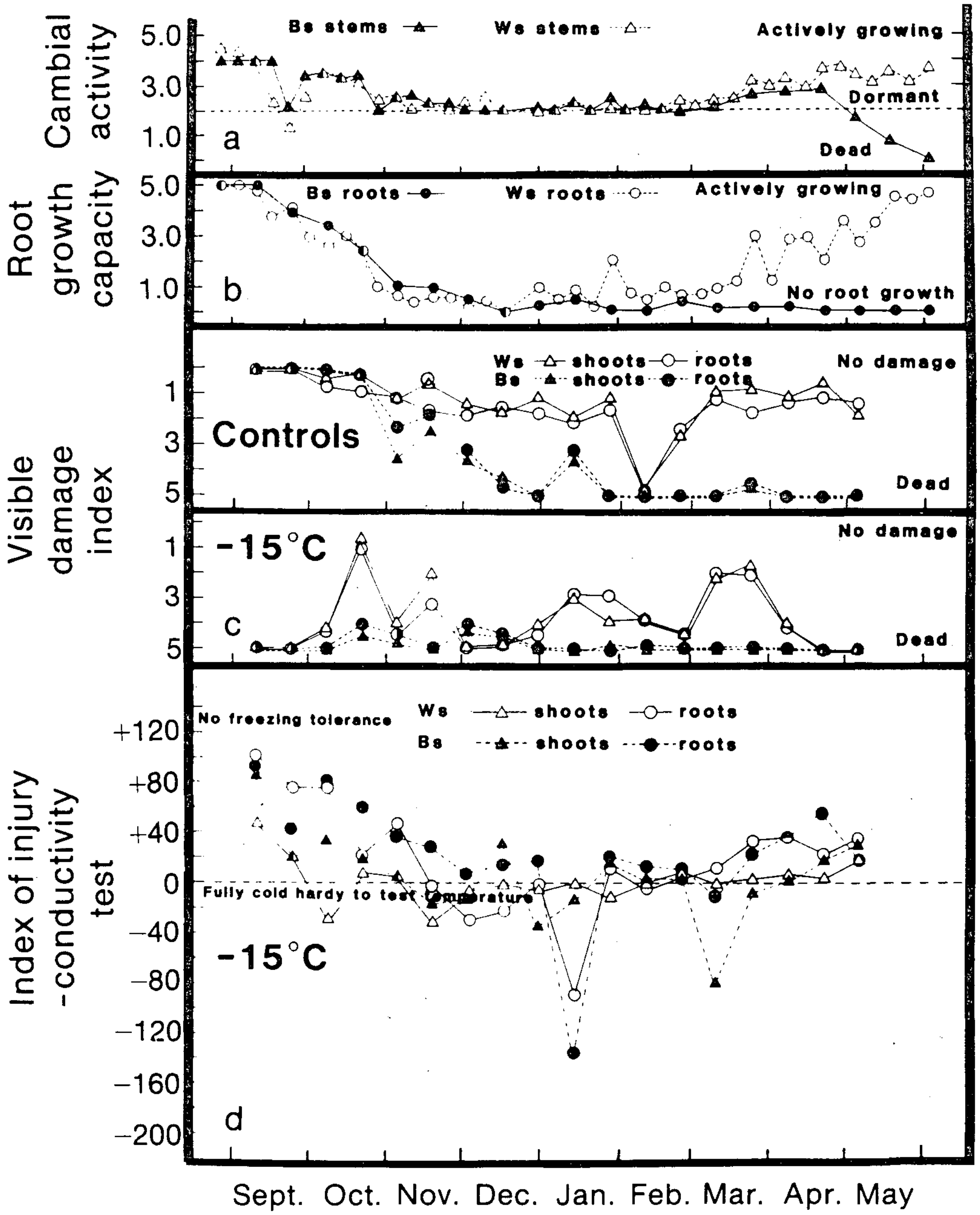

Figure 4. **Comparison dormancy, freezing tolerance, and visible damage data for black spruce (Bs) and white spruce (Ws) seedling shoots and roots during the 1984-85 overwintering period.**

Cambial activity, root growth capacity freezing tolerance tests to -15°C, conductivity tests on seedling shoots and roots, and visible damage assessments were carried out according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, visible damage index, index of injury-conductivity) or 20 (root growth capacity) seedling shoots or roots.

seed orchards will undoubtedly provide key information to assist nursery personnel in the effective management of their resources and in monitoring the progress of their stock.

REFERENCES

Burdett, A.N. 1979. New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. Can. J. For. Res. 9:63-67.

Carlson, L.W. 1983. Guidelines for rearing containerized conifer seedlings in the prairie provinces. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-214E. Revised.

Colombo, S.J.; Webb, D.P.; Glerum, C. 1984. Frost hardiness testing: an operational manual for use with extended greenhouse culture. Ontario Minist. Nat. Resour. For. Res. Rep. 110.

D'Aoust, A.L.; Cameron, S.I. 1982. The effect of dormancy induction, low temperatures and moisture stress on cold hardening of containerized black spruce seedlings. Pages 153-161 *in* J.B. Scarratt, C. Glerum, and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp. Environ. Can., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. Inf. Rep. O-P-10.

DeLucia, E.H.; Smith, W.K. 1987. Air and soil temperature limitations on photosynthesis in Engelmann spruce during summer. Can. J. For. Res. 17:527-533.

Dymock, I.J.; Dendwick, F.M. 1987. Monitoring viability of overwintering container stock. Pages 21-35 *in* E.M. Harvey, compiler. Proc. 1986 Prairie Fed.-Prov. Nurserymen's Meet. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-287.

Edwards, I.K. 1987. Nutrient regimes and cold hardiness in conifer seedlings. Pages 14-17 *in* E.M. Harvey, compiler. Proc. 1986 Prairie Fed.-Prov. Nurserymen's Meet. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-287.

Ferguson, R.B.; Ryker, R.A.; Ballard, F.D. 1975. Portable oscilloscope technique for detecting dormancy in nursery stock. U.S. Dep. Agric., For. Serv., Ogden, Utah. Gen. Tech. Rep. INT-26.

Hare, F.K.; Thomas, M.K. 1974. Climate Canada. Wiley Canada Ltd., Toronto, Ont.

Kramer, P.J.; Kozlowski, T.T. 1979. Physiology of woody plants. Academic Press, New York, N.Y.

Levitt, J. 1980. Responses of plants to environmental stress. Vol. 1: Chilling, freezing and high temperature stresses. Second ed. Academic Press, New York, N.Y.

Tinus, R.W. 1982. Environmental control of seedling physiology. Pages 75-82 *in* J.B. Scarratt, C. Glerum, and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp. Environ. Can., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. Inf. Rep.

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