Monitoring Viability of Overwintering Container Stock in the Prairies — An Overview of a Five Year Lodgepole Pine Study[1]

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Abstract. Overwintering viability of first year containerized lodgepole pine seedlings was monitored using a series of morphological assessments, dormancy tests and freezing tolerance(cold hardiness) tests. Results presented outline the phenology of dormancy and cold hardiness development. The impact of environmental factors is discussed in relation to the overwintering success.

INTRODUCTION

This presentation will provide some insight into the study results obtained from our research on monitoring viability of overwintering container stock. We have been working with five species of conifer seedlings that are grown for reforestation purposes on the Canadian prairies. At this time, I will restrict my talk to our lodgepole pine data.

In a production nursery situation, where containerized stock is to be overwintered outdoors, nursery personnel can rely on the shortening natural photoperiod, during the latter part of the summer, to initiate the onset of dormancy in their seedlings. The gradual reduction in the day and night temperatures triggers the gradual development of cold hardiness.

While the induction of dormancy and cold hardiness is achieved under ambient conditions, it often must be achieved in a relatively short period. This is particularly true for nurseries in cold temperate regions, where early frosts can be a serious problem.

It is therefore imperative, for the nursery personnel to have a good understanding of the basic physiology involved in successful overwintering of container seedlings. It is also important for staff to have rapid and reliable tests at their disposal in order to monitor the development of dormancy and cold hardiness in their seedlings.

Our study on overwintering physiology had three purposes then, in light of the preceding discussion:

1. To evaluate methods for the determination or testing of seedling dormancy and cold hardiness.

2. To investigate the relationships between terminal buds, the stem(cambium) and roots, and the phenology of dormancy and cold hardiness development during overwintering.

3. To provide a better understanding of the basic physiology of overwintering in conifer seedlings that could aid in the development of improved nursery management practices.

The results presented will provide you with an overview of five year's efforts in this study.

MATERIALS AND METHODS

Rearing and sampling schedules

Seedlings of lodgepole pine(*Pinus contorta* var. *latifolia* Engelm.) were reared in Spencer-Lemaire Fives according to the methods of Carlson(1983), using schedule 2 for hardiness zone 3.

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Details of the rearing and sampling schedules can be found in Dymock and Dendwick(1987, 1988).

Morphological assessments

The morphological assessments made at the initial time of sampling included the following: height and root collar diameter measurements; visible damage assessment of seedling shoots, needles, buds and roots; shoot and root fresh(FW) and oven dry weights(DW); calculation of seedling shoot/root ratios(S/R) based on fresh and dry weights; and the calculation of shoot and root moisture content.

Dormancy tests

Dormancy tests were conducted on stems(cambium) using the oscilloscope-/square wave deformation(SWD) technique of Ferguson, Ryker and Ballard(1975), but using the coding system of Dymock and Dendwick(1987).

Root dormancy was monitored using the root growth capacity(RGC) method of Burdett(1979) and the scoring system for estimating the numbers of new roots over one cm in length.

Shoot(bud) dormancy was monitored by determining the time to bud break (TTBB) using conditions similar to those used in the RGC test. Seedlings remained in the greenhouse until all buds had broken and seedlings were fully flushed. The average number of days to complete bud break(TTBB) were then calculated.

Freezing tolerance tests

Initial tests were carried out during 1983-84 using rapid freeze/thaw cycles. Whole seedlings in containers were placed in cold rooms or freezers set at -5C, -10C and -15C for 6, 24, or 168 hr. Control seedlings were left at 20C. At the designated times, seedlings were rapidly brought to room temperature, subjected to oscilloscope/SWD testing and then moved to the greenhouse.

Four weeks later, shoots and roots were assessed for visible damage. Shoot and root assessments were added to yield a seedling survival rating. Seedlings rated -5 or higher, were considered survivors, while those rated below -5 had little chance of survival.

The rating system used to assess visible damage to shoots and roots, was modified from the one previously reported by Dymock and Dendwick(1987). It has been modified to more accurately reflect degrees of damage, and is as follows:

Rating	Symptoms of pine shoot damage
0	No visible damage to the shoot terminal, stem or needles.
-1	Terminal bud alive; no apparent stem damage; < 20% dead needles.
-2	Terminal bud alive; no apparent stem damage; 20-50% dead needles.
-3	Terminal bud alive but shows some damage; 50-90% dead needles.
-4	Terminal bud dead; most of upper stem and lateral branches dead; < 10% live needles, most of them emerging from lower stem area.
-5	Shoot completely dead; no living tissue present.

Rating	Symptoms of pine root damage
0	More than 10 new roots > 10 cm long; many white root tips.
-1	4-10 new roots > 10 cm long.
-2	1-3 new roots > 10 cm long.
-3	Some new roots, but none > 10 cm long; some white root tips.
-4	No new roots or white root tips; some loss of turgor in old roots.
-5	No live roots; roots dark brown to black in colour; no turgor; bacterial/fungal growth evident.

Supplemental freezing tolerance tests were carried out during the 1984-85, 1985-86 and 1986-87 seasons. Whole seedlings in containers were subjected to -5C, -10C and -15C for 24 hr periods only. Controls were maintained at +5C.

After 24 hr, seedlings were rapidly thawed and brought to room temperature. Conductivity testing of shoots and roots was done using the method of Colombo, Webb and Glerum(1984) but with those modifications reported by Dymock and Dendwick(1987). Seedlings were also potted and returned to greenhouse conditions for visible damage assessments four weeks later.

From the conductivity test results, the mean percent relative conductivities of shoots and roots were calculated. The index of injury for each set of shoots and roots from each freezing temperature was then calculated according to Colombo et. al.(1984).

Environmental parameters

Weather records were collected over each overwintering period. These include the period from the time seedlings were moved outdoors to the shadeframes, until the following spring.

Shoot temperatures(at bud height), root plug temperatures, and air temperatures at 1.8 metres, were routinely monitored using a Campbell Scientific CR-7 Micrologger equipped with copper-constantan thermocouples.

Long term records, and corroborating daily records from the closest local weather stations, were obtained, from the Canadian Climate Control Centre of Environment Canada(Downsview, Ont.).

RESULTS

Morphological assessments

Seedling height and root collar diameter measurements from all five study seasons are shown in figure 1. In all cases, height growth was completed prior to late August. Root collar diame-

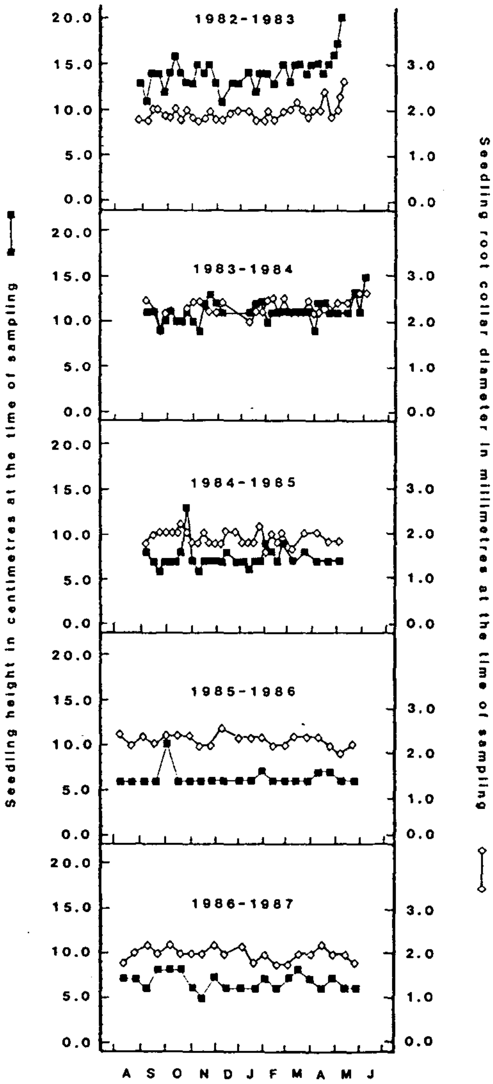


Figure 1. Comparative seasonal changes in height and root collar diameter over five overwintering periods.

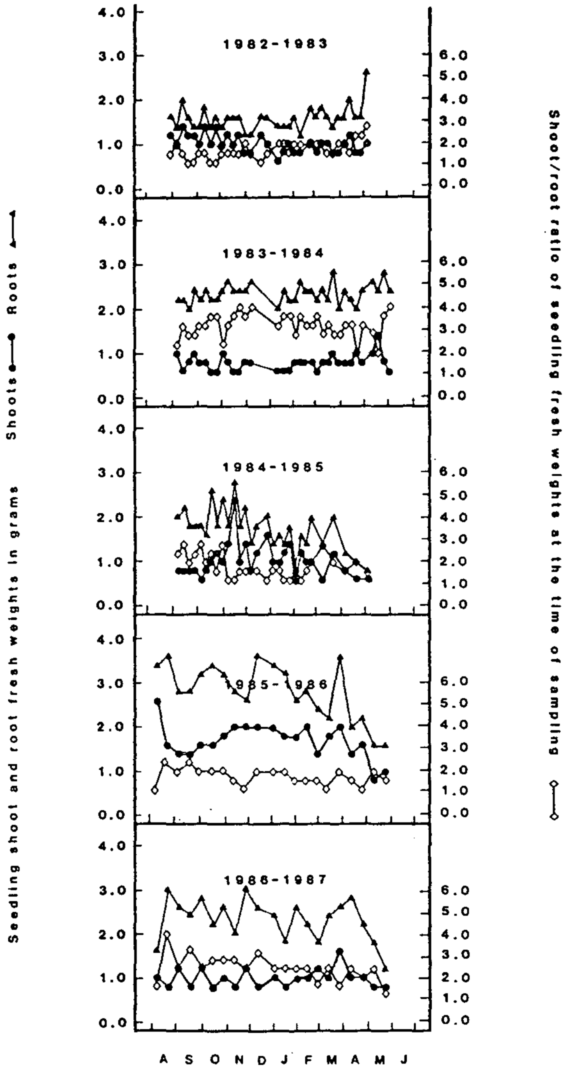


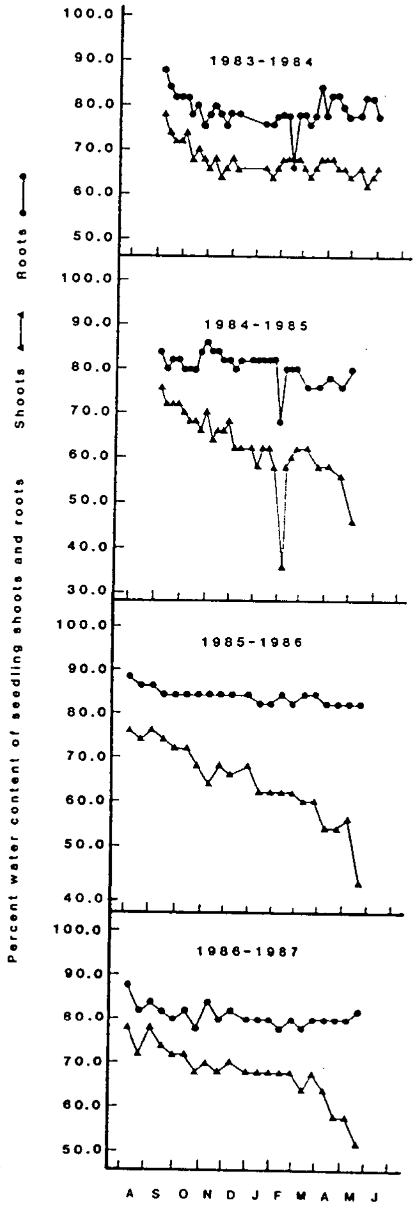
Figure 2. Comparative seasonal changes in shoot and root fresh weights and shoot/root ratio of fresh weights over five overwintering periods.

ter continued to increase for some time yet into September. No appreciable changes in either parameter would be expected again until spring, as seedlings begin to flush.

Height began to increase again in the springs of 1983 and 1984 but not in each of the following three years(fig. 1). Similar results are seen for root collar diameter measurements(fig. 1).

Parallel results can be seen in figure 2 for the shoot and root fresh weights and the S/R(FW) ratios. In the latter three seasons, pronounced drops in mean shoot fresh weights are quite evident.These began at different times, but always closely following the early loss of snow cover from the seedlings (data not shown).

There was no comparable decline in either the shoot(or root) dry weights (data not shown). However, the shoot FW loss that is seen in figure 2, is clearly seen in figure 3 as a loss in shoot water. This was observed in each of the 1984-85, 1985-86 and 1986-87 seasons. The rapid loss of shoot water content closely paralleled the loss of snow cover from the shoots(data not shown).



igure 3. Comparative seasonal changes in shoot and root moisture content over four overwintering periods.

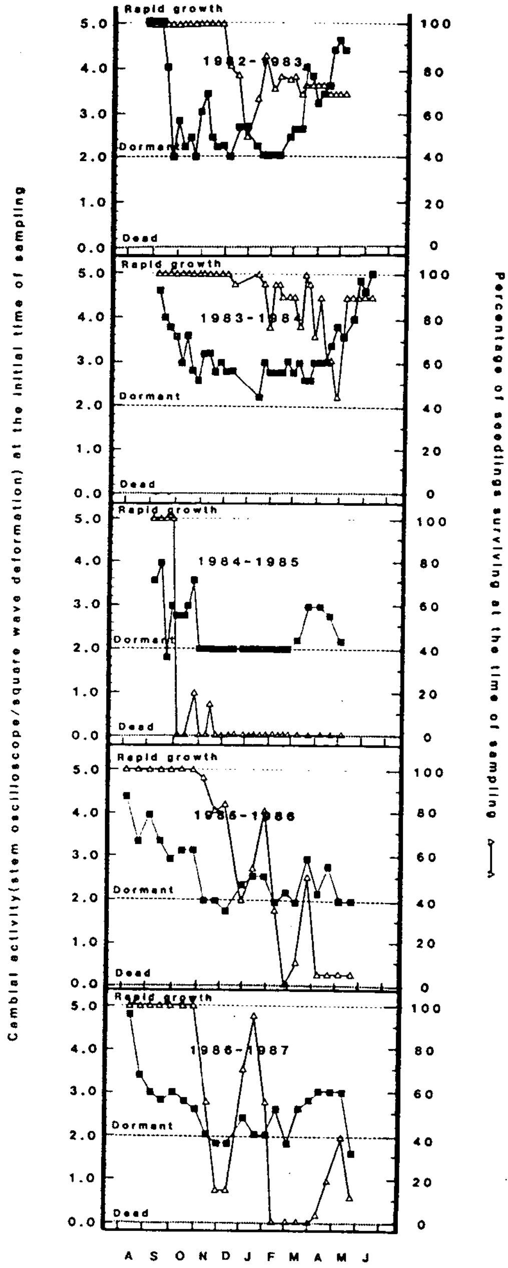


Figure 4. Comparative stem activity and percent seedling survival over five overwintering periods.

Dormancy tests

Stem(cambial) activity declined during the fall of the year, although this was quite variable(fig. 4). Stem activity was quite variable during the winter months. Only during the 1984-85 season did stem activity appear to remain dormant for a prolonged period.

Seedling survival throughout the sampling periods, was highly variable, as seen in figure 4. It generally showed a mid-winter decline during most of the study seasons, and began to increase again towards the spring in some but not all seasons.

Root dormancy, as monitored by the RGC test, dropped with time during the early fall months, but this was quite variable(fig. 5). During 1983-84, there was a slow increase in RGC as seedlings came out of dormancy in the late spring. However, during each of the three succeeding seasons, little sustained root activity was observed after mid-winter.

Shoot(bud) dormancy, as monitored using the TTBB test, showed a much more regular annual pattern as seen in figure 5. The TTBB was very high initially in

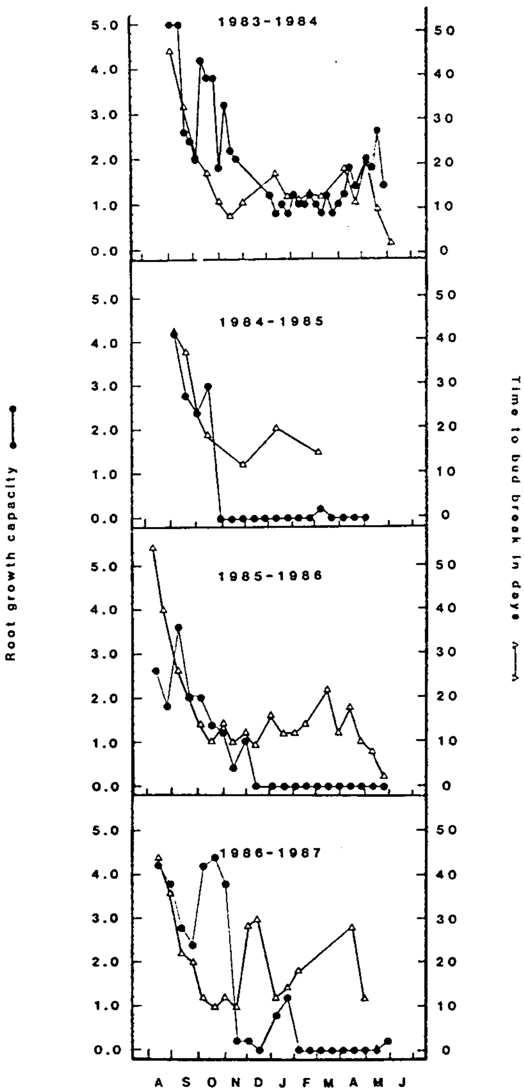


Figure 5. Comparative root growth capacity and time to bud break over four overwintering periods.

each season and declined to an early minimum by November of each year. Secondary increases in TTBB occurred later during most winters before dropping off prior to the spring flush.

Freezing tolerance tests

Results of initial freezing tests during 1983-84, are shown in figure 7. The seasonal trends in stem activity, and freezing tolerance of seedling shoots and roots are seen quite clearly.

Rigorous nonparametric statistical testing was conducted on the results. Temperature comparisons within the duration classes were conducted for each parameter(ie. oscilloscope/SWD trace; shoot damage; root damage). Results showed that as the freezing temperature decreased, the damage increased, giving the ordering as: Controls<-5C<-10C<-15C for all classes(data not shown).

Similar analyses of duration comparisons within the temperature classes were conducted. Initial tests indicated that there was an ordering effect for duration with respect to shoot damage for each temperature(6hr<24hr<168hr), but only for roots at -5C. Duration had no significant effect on stem activity.

Further analysis indicated that duration had a significant effect on shoot damage between 6 and 168 hr at -5C and -10C, but had only a marginal effect at -15C. There was only a significant duration effect on root damage at -5C (data not shown).

During the 1984-85, 1985-86 and 1986-87 seasons, supplemental freezing tolerance tests were conducted for 24 hr only. The results are shown in figure 7. It can be seen that seedlings in these three years were unable to reach the same levels of hardiness that were reached by seedlings from the same seedlot, during the 1983-84 season(fig. 6).

Results from conductivity testing of shoots and roots indicated that roots were slower to harden than shoots. It was also shown that the roots did not achieve the same levels of hardiness to the lower test temperatures(data not shown). This was also seen, but to a lesser extent, in figure 7 with respect to shoot and root visible damage.

Environmental parameters

Figure 8 shows the weather records for each of the overwintering seasons in this study. In the first portion of this

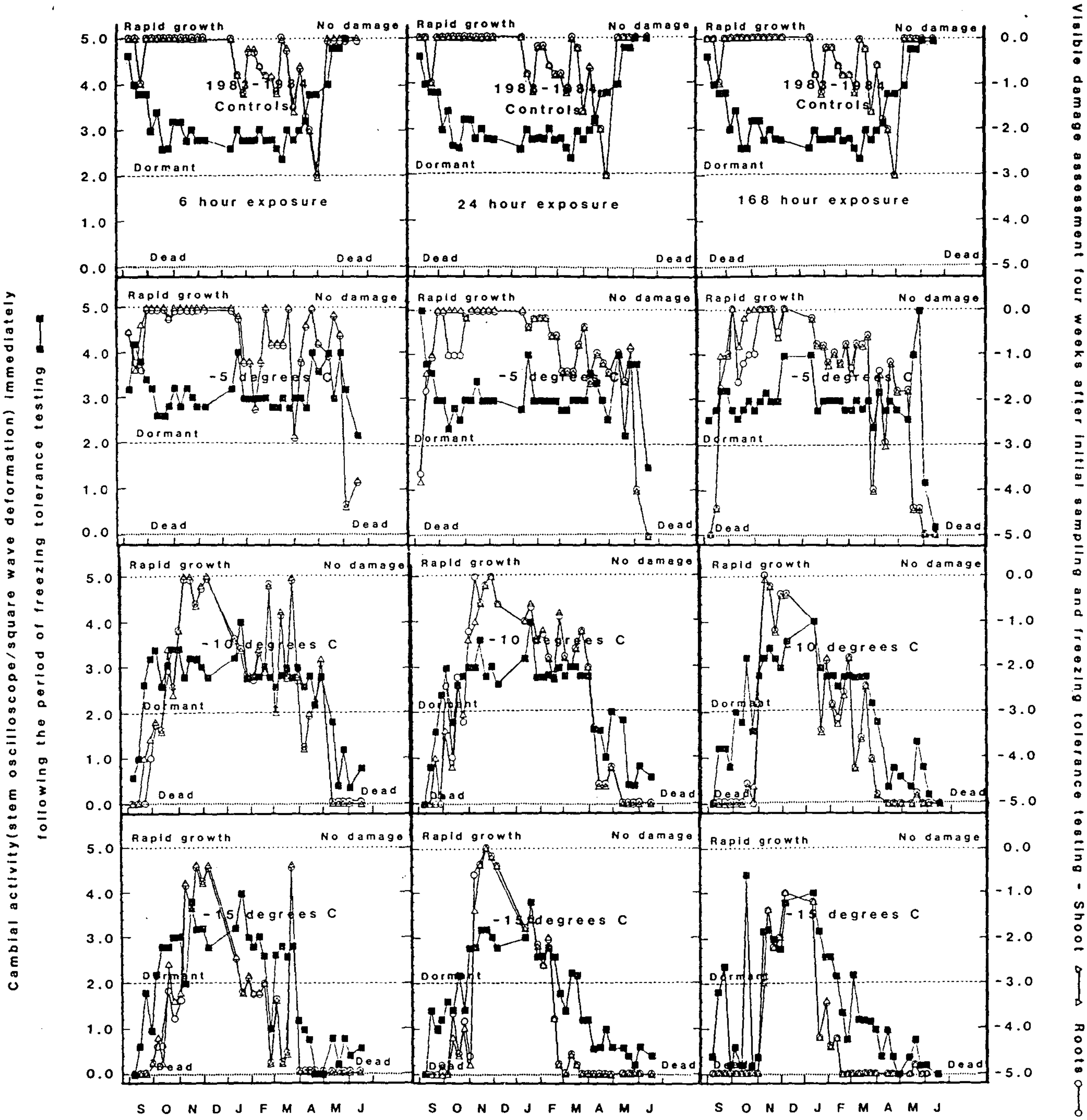


Figure 6. Influence of freezing temperatures and duration of exposure on stem(cambial) activity and visible damage to shoots and roots during the 1983-84 overwintering period.

figure(fig. 8a), are plotted the values for the mean daily minimum and maximum temperatures for the 30 year period from 1941-1970. Also shown are the daily extreme minimum and extreme maximum temperatures from 100 year records to 1981.

The mean annual period from first to last frost, growing-degree days, and hardening-degree days, derived from the 1941-70 period, are also shown(fig 8a). The daily range in temperatures, from minimum to maximum, are indicated by the

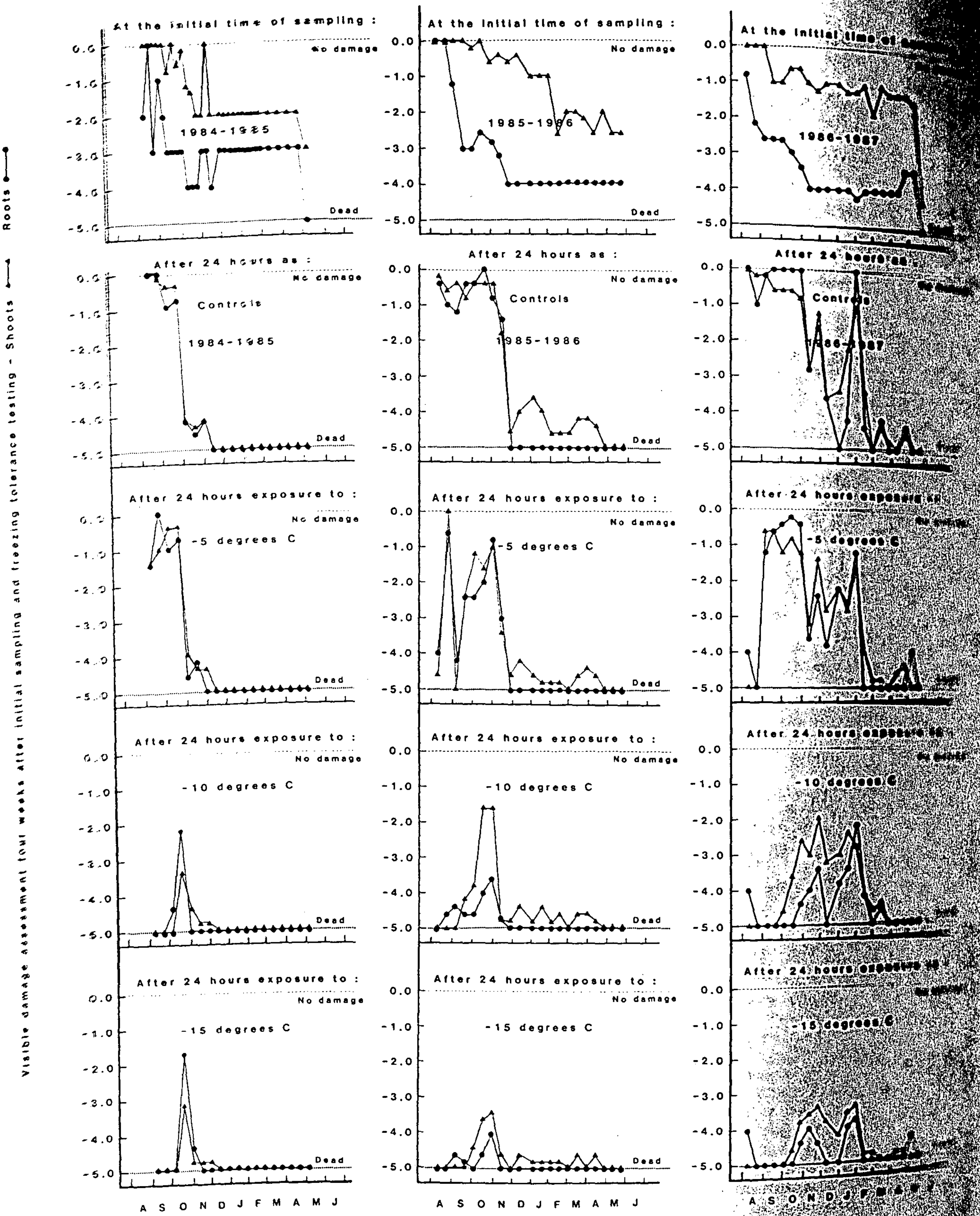


Figure 7. Comparative influence of freezing temperatures on visible damage to shoots and roots over the 1984-85, 1985-86 and 1986-87 overwintering seasons.

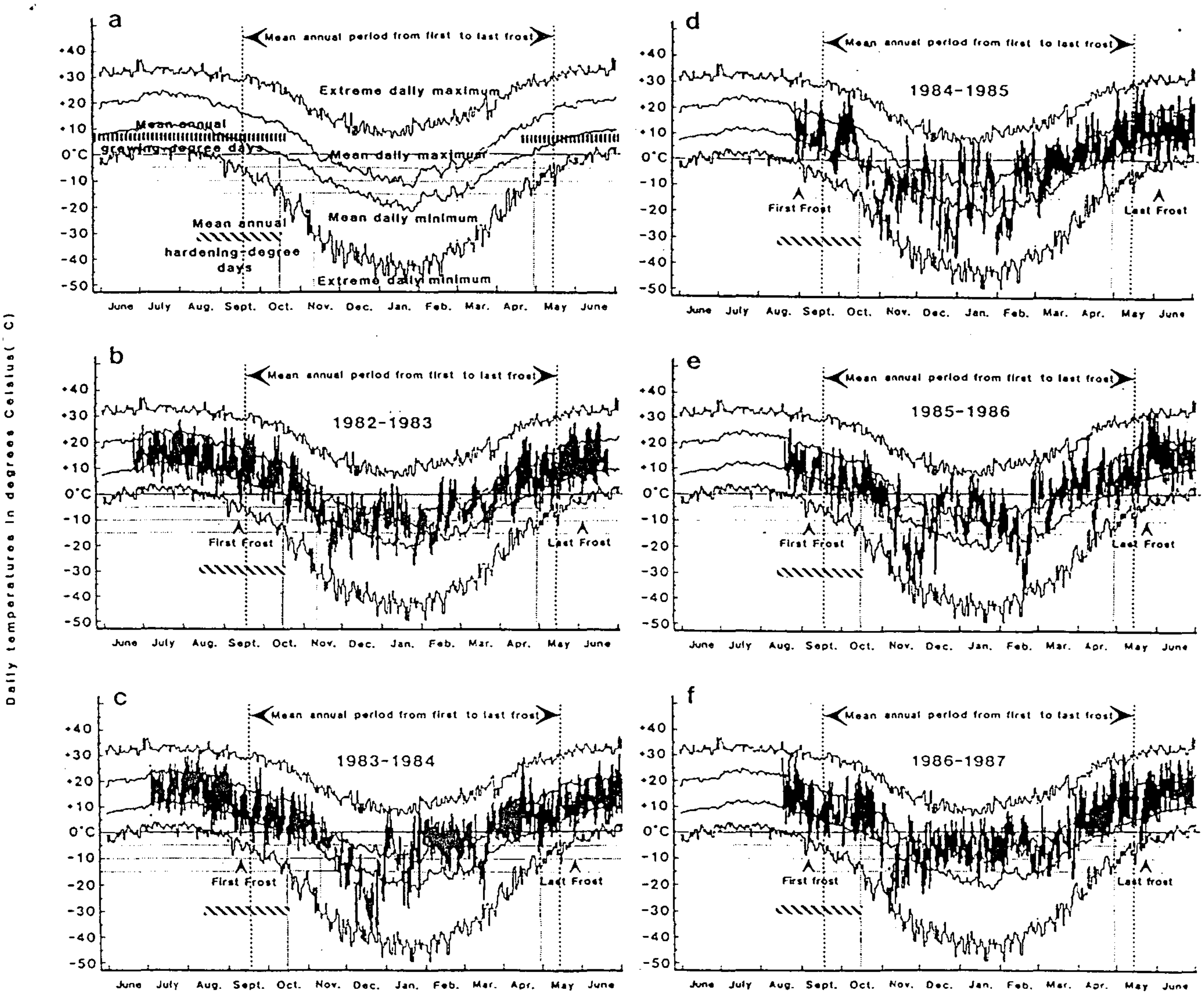


Figure 8. Mean daily temperature data for the 1941-70 period for Edmonton, Alberta and the daily records for each overwintering season.

ertical black bars that overlay the ıeans(fig. 8b-8f). They begin on the day hat seedlings were moved outdoors, and ontinue through to the end of the sam- ling season the following spring.

These records, and the impact of he environmental parameters are the rimary focal point for the remainder of his presentation.

DISCUSSION

The principle feature that can be iscerned from the weather records in igure 8, is that the 1982-83, 1983-84 nd 1986-87 seasons were closest to normal (ie. the 30 year means) during the critical hardening period.

This period can be considered to occur from the time that the seedlings are moved outdoors, to the middle of November(fig. 8). At this point, for 1983-84, seedling shoots and roots were approaching their most hardy state, relative to -15C(fig. 6)

There are 295.8 cumulative hardening-degree days that can be expected between August 14 and October 18. The cumulative hardening-degree days for each season, and the percentage deviations from the expected mean were:

1982-83	336.5(+13.8%)
1983-84	270.5(- 8.6%)
1984-85	172.5(-41.7%)
1985-86	191.5(-35.3%)
1986-87	281.3(- 4.9%)

During the first year of freezing tolerance testing(1983-84), the number of hardening-degree days just fell short of the expected mean(-8.6%).

For each of the next two seasons in 1984-85 and 1985-86, seedlings were subjected to temperature variations that were frequent and unusually severe. They often occurred during the early hardening stages(figs. 8d and 8e). Warming cycles also presented problems as will be discussed shortly.

For 1984-85, the large drop in the hardening-degree days was likely due to the numbers and severity of early frost events that occurred during late August and throughout September(fig. 8d). They were followed by very severe conditions and early snows in mid-October that persisted well into the winter months.

These conditions greatly decreased the potential number of hardening-degree days for the seedlings. They were more than sufficient to arrest any further development of cold hardiness, as has been shown in figure 7. There was also a significant impact on stem activity and seedling survival(fig.4), and on bud and root dormancy(fig. 5). The end result, was a crop that had insufficient time to properly achieve full dormancy and cold hardiness.

Similar extremes were experienced in the 1985-86 crop. The conditions that occurred during the critical hardening period significantly retarded the full development of a satisfactory overwintering state.

This was further exacerbated by unusually mild conditions during the second half of the winter(fig. 8e). This in turn contributed to the shoot damage that became apparent(figs. 2 and 3) with the loss of snow cover. Survival then dropped rapidly(fig. 4), due to the loss of water from the shoots.

In both years, there was little capacity for any new root growth(fig.5). This was partially due to the failure of roots to sufficiently harden during the fall, due to the numbers and severity of early frosts. Shoots of those seedlings brought indoors for testing, continued to flush, at least initially. They did perish, however, due to their inability to generate new roots, caused by the earlier freezing damage(fig. 5).

In 1986-87, hardiness developed along normal lines(fig. 7), but did not reach the levels observed in 1983-84 (fig. 6). This crop started to decline in survival during late January 1987. This was at the time when very warm temperatures developed, and snow cover was lost. These conditions were prevalent throughout the rest of the winter and into the spring.

The now exposed shoots suffered from rapid water loss and winter drying, with the advent of above freezing temperatures(fig. 8f). The still frozen roots were unable to replace the water lost from the shoots(fig. 3), due to increased metabolic activity, and seedling mortality increased(fig. 4).

SUMMARY AND CONCLUSIONS

In the latter three seasons, the failure of each overwintering crop was due to two factors. Initially, these were due to the early and severe frosts. These were then coupled with warming temperatures during the latter part of the winter, which precipitated increased seedling mortality due to winter drying of exposed shoots.

Each test utilized in this study was useful in monitoring the progress of the seedlings as dormancy and cold hardiness developed. Each provided a good evaluation of seedling status, for the parameter under investigation, at each of the sampling dates.

When this point information was combined over a season and compared to the environmental data, then reasons for the success or failure of the crop became apparent. This type of testing and analysis, then, is of paramount importance for nurseries that overwinter container crops outdoors.

Point sampling lets staff monitor viability of the stock and should allow for precautionary protective measures to be taken, in advance, when adverse weather conditions are expected. Similar sampling and testing immediately following exposure to severe conditions, also allows for a fairly rapid diagnosis of damage that may have been incurred.

These tests and the information derived from them, then, would provide nursery management with an additional tool to aid in decisions on the ultimate fate of the stock.

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