Keepability of Pennsylvania versus West Coast Grown Douglas-Fir Christmas Trees: Genotypic Variation in Relation to Subfreezing Temperatures

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ABSTRACT. Cut Douglas-fir Christmas trees grown in Pennsylvania from Rocky Mountain seed sources and coastal trees grown in the Pacific Northwest and shipped into Pennsylvania were compared for keepability. Following various cold treatments, the cut ends of trees were placed in water in an indoor display area. Coastal trees placed in a freezer at -29°C for 24 h had 89 ± 5.1% (mean ± standard error) needle loss after one day of display, while Rocky Mountain origin trees exhibited only 3 ± 2.0% needle loss after 1 day and 50 ± 5.6% needle loss after 18 days. Coastal produced trees exposed to temperatures > -12°C had 50 ± 9.8% needle loss at the end of the experiment, while Rocky Mountain trees ended with 22 ± 3.2% needle loss. Four additional treatments consisted of trees placed on an outdoor lot and periodically moved indoors to simulate Christmas tree market activity. Again, there was a significant difference between trees from coastal and Rocky Mountain sources, with 57.2 ± 4.3% and 11.8 ± 1.2% needle loss after 3 days, respectively. By the end of the 23 day experiment, the coastal trees were essentially devoid of needles, whereas Rocky Mountain trees had an average of only 20% needle loss. Coastal trees also exhibited a very noticeable loss of color and luster.


In recent years, Douglas-fir has gained popularity as a Christmas tree in the Northeast United States. The soft, short foliage and pleasant citrus fragrance of Douglas-fir are some of the qualities which consumers find attractive. However, one of the most important qualities of any Christmas tree species is the ability to maintain a fresh appearance for a reasonably long display period. Among the physiological properties that are necessary for this extended “keepability” is a tree’s ability to withstand cold temperatures as well as some degree of desiccation.

When frost damage occurs in evergreen conifers, the rigid fibers in the needles prevent them from wilting. The damage may go unnoticed until the tree thaws and the needles lose color and become brittle. In fact, needle drop resulting from either freezing or desiccation will not readily occur in Douglas-fir until the tree thaws or is rehydrated (Chastagner 1986). Interestingly, there is evidence of a correlation between freezing tolerance and drought tolerance (Levitt 1980).

The degree to which a tree is able to withstand drought or cold temperatures depends upon its genetic makeup and whether it was given an opportunity to acclimate to these stress factors. For example, a tree that has cold hardened may withstand temperatures to -200°C, however, that same tree will be readily killed at temperatures a few degrees below freezing if it is not allowed to cold harden (Kramer and Kozlowski 1979). Moreover, when a tree species has a large geographic range, there is a high probability that the genetic makeup of widely dispersed trees is quite different (Abrams 1988). Trees growing in habitats that rarely experience very cold temperatures will not be able to acclimate to the degree seen in trees repeatedly exposed to cold.

Throughout its extensive range, three distinct varieties of Douglas-fir have been identified: coastal or green, inland or gray, and Rocky Mountain or blue. Trees of each of these varieties have their own particular requirements for moisture, temperature, and other environmental factors. As it turns out, the Rocky Mountain-blue variety is best suited to grow in the climate of Pennsylvania and much of the central and northeastern United States, whereas the coastal-green variety generally cannot tolerate the cold winters of these regions.

On the East Coast, demand for Douglas-fir Christmas trees has increased in recent years. Western growers, primarily from Washington and Oregon where this species comprises about 74% of Christmas tree production (Michaels and Chastagner 1984), have found it profitable to ship trees into eastern market areas. However, many retail lot operators and consumers are finding that some Douglas-fir trees do not have the keepability they would expect. In fact, some consumers have complained of having to remove their tree after just 2–3 days of display. The purpose of this study was to determine if subfreezing temperatures differentially affected the keepability of coastal variety trees shipped from the Pacific.
Northwest versus Rocky Mountain trees grown in Pennsylvania.

METHODS
In late November and Early December, 1988, 35 coastal (Pacific Northwest-green variety) and 35 Pennsylvania grown (Rocky Mountain-blue variety) were brought to the Pennsylvania State University campus. All trees were USDA premium grade, in the 6-7 ft size class, and cut in mid to late November. Samples of each source were inspected and were determined to be free of disease, reducing the possibility of needle loss due to infectious agents (Chastagner et al., 1984, Michaels and Chastagner 1984).

The two sources were randomly divided into 7 groups of 10 trees (5 trees from each source). Group 1 was placed in a freezer at -29°C for 24 hours and then moved to a heated room for indoor display. Group 2 was taken immediately indoors for display, avoiding exposure to very cold temperatures. Groups 3-7 were placed outdoors in a simulated outdoor retail lot, where group 7 remained for the entire experiment. Groups 3-6 were taken indoors at 2-day intervals to simulate typical market activity.

The trees were placed indoors in a completely randomized design. A 2-in. section was trimmed from the base, and the trees were then kept in water. Temperature and relative humidity (RH) were monitored with a hygro-thermograph at both the indoor and outdoor locations. Needle loss was measured at 2-day intervals by tagging 2 twigs per tree (mid-crown), and counting the number of needles retained in a 5 cm section of current year growth. Each twig was gently passed between thumb and forefinger to dislodge any loose needles (Chastagner 1986). In addition, xylem water potential (Ψ Wilhelm) was measured every 2 days by placing a 5-6 cm terminal twig section from mid-crown in a pressure chamber (Kellihar et al. 1984).

At the end of the experiment, total leaf scars were counted for each 5 cm twig section so that needle loss could be expressed as a percentage of the total. Data were analyzed using one-way analysis of variance (Neter et al. 1985). The experiment ran from 9 Dec., 1988 through 4 Jan., 1989.

RESULTS AND DISCUSSION
The USDA standards for Christmas tree grades (revised 11/89) identifies a grade 2 Douglas-fir as having 30% to 70% foliage cover of the branches. Grade 1 trees have 70% to 90%, and premium grade above 90% foliage cover. Anything below 50% foliar coverage is considered cull. Therefore, for the purpose of this paper, 50% needle loss will be considered the point at which a tree is no longer acceptable. Although, a consumer may well find that a tree with 60% foliage coverage (representing a 30% reduction) is unacceptable for a tree originally purchased as a premium grade tree.

During the study period, indoor temperature and RH ranged from 18° to 22°C and from 30% to 70%, respectively. Outdoor temperature ranged from -22° to 17°C (Fig. 1) and RH ranged from 20% to 100%. On 14 out of the 27 days, outdoor temperature dropped below 0°C. Only Group 2 trees (those taken indoors at the onset of the experiment) were not exposed to the very cold weather which occurred during the experiment.

In each group there was a striking difference in needle loss between the coastal variety trees grown on the West Coast and those from Rocky Mountain seed sources grown in Pennsylvania. There was, however, some variability between the treatment groups in the amount of time required for a difference to develop. The coastal variety trees that were placed in the freezer (Group 1) had 89 ± 5% (mean ± standard error) needle loss after only 1 day of display, and 100% needle loss by day 12 (Fig. 2). In contrast, the Penn/Rocky Mtn Group 1 trees exhibited 13 ± 4, 30 ± 7, and 50 ± 6% needle loss after 3, 12, and 19 days, respectively. Sakai and Weiser (1973) found the damage threshold for leaf tissues in Rocky Mountain and coastal Douglas-fir to be -40°C and -20°C, respectively. However, these thresholds were determined after tissues were given adequate time for cold acclimation. The deterioration which occurred in the Penn/Rocky Mtn trees frozen at -29°C in this study may have been due to their acclimation period being interrupted by harvesting, while the damage in coastal trees may have been due to a combination of nonacclimation and their limited cold temperature threshold. McCreary (1984) found a threshold of -11°C in coastal Douglas-fir seedlings placed in cold storage, which may have been due to root rather than shoot damage.

Group 2 (never subjected to temperatures below -12°C) had the best performance of the coastal variety trees, with a reduction to grade 1, grade 2, and cull in 3, 12, and 24 days, respectively (Fig. 3). Group 2 Penn/Rocky Mtn trees, however, were reduced to grade 1 in 5 days and remained in that condition for the duration of the study; these trees finished with a 22 ± 3% average needle loss. Although the coastal trees in this group were not exposed to the threshold of -20°C, their keepability was greatly reduced.

Obvious differences in needle retention were again found in the trees that were periodically brought indoors from the outdoor lot (Groups 3-6). There was no significant difference between Groups 3-6 of the same seed source; therefore, data for these groups were pooled within each source for further analysis. The coastal trees consistently deteriorated more rapidly (P < 0.05) than the Penn/ Rocky Mtn trees (Fig. 4). Although the coastal trees appeared to be in good condition while on the outdoor lot, they deteriorated very quickly once they were placed indoors. After 3 days indoors, the coastal trees in Groups 3-6 averaged 57 ± 4% needle loss. The low standard error associated with this treatment mean indicates a consistency among these coastal trees, despite varying exposure time to subfreezing temperatures, suggesting that the damage threshold for the coastal trees had been reached.

Fig. 1. Daily high and low temperatures at a simulated outdoor Christmas tree retail lot at The Pennsylvania State University. Numbers 2-6 on the X-axis indicate the day on which the respective treatments were transferred indoors.
ditional time outdoors had negligible impact on their keepability. Penn/Rocky Mtn trees in Groups 3–6 were relatively unaffected by the cold temperatures. For the pooled data, average needle loss after 3 days of indoor display was 12 ± 1% and only 20 ± 1% at the conclusion of the experiment. All of the coastal trees remained on the outdoor lot (Group 7) were cur by day 12 (Fig. 5). The period of most rapid needle loss for these trees coincided with warming temperatures (Fig. 1 & 5). Penn/Rocky Mtn trees in Group 7 reduced to grade 1 in 5 days and remained in acceptable condition to the finish of the experiment, with a 15 ± 3% average needle loss.

Fig. 2. Mean percent needle loss versus days indoors for coastal and Pennsylvania grown Douglas-fir Christmas trees after being frozen at −29°C for 24 h. Intercept (day 0) represents needle loss prior to freezing. Vertical bars represent ± standard error. Standard errors for coastal trees were negligible.

Fig. 3. Mean percent needle loss versus days indoors for coastal and Pennsylvania grown Douglas-fir Christmas trees that were never subjected to temperatures below −12°C. Intercept represents needle loss prior to being placed indoors. Vertical bars represent ± standard error.

Fig. 4. Mean percent needle loss versus days indoors for coastal and Pennsylvania grown Douglas-fir Christmas trees that were periodically taken indoors from a simulated outdoor retail lot. Intercept represents needle loss prior to being placed indoors. Vertical bars represent ± standard error. Standard errors for Pennsylvania grown trees were negligible.

The greatest deterioration of coastal trees occurred soon after trees exposed to subfreezing temperature were brought indoors, and not while they were on the retail lot. This should be of great concern to retailers and consumers. The deterioration was rapid enough so that all coastal trees exposed to temperatures less than −12°C were unacceptable (more than 50% needle loss) after just 3 days of display. With the exception of Group 1 (trees placed in the freezer), all Penn/Rocky Mtn trees were in acceptable condition, with less than 30% needle loss, for the entire experiment. The needle loss that occurred in the coastal trees was also accompanied by a very noticeable loss of color and luster. One of the differences between desiccation and freezing injury is that needles lost due to desiccation still appear to be fresh (Chastagner 1986), while those which are frozen experience notable color loss. The only Penn/Rocky Mtn trees that exhibited color loss to a similar degree were those placed in the freezer.

CONCLUSIONS AND APPLICATION

There were great differences in keepability between Pacific Northwest grown coastal variety and Pennsylvania grown Rocky Mountain variety Douglas-fir Christmas trees in this study. The greatest deterioration of coastal trees occurred soon after trees exposed to subfreezing temperature were brought indoors, and not while they were on the retail lot. This should be of great concern to retailers and consumers. The deterioration was rapid enough so that all coastal trees exposed to temperatures less than −12°C were unacceptable (more than 50% needle loss) after just 3 days of display. With the exception of Group 1 (trees placed in the freezer), all Penn/Rocky Mtn trees were in acceptable condition, with less than 30% needle loss, for the entire experiment. The needle loss that occurred in the coastal trees was also accompanied by a very noticeable loss of color and luster. One of the differences between desiccation and freezing injury is that needles lost due to desiccation still appear to be fresh (Chastagner 1986), while those which are frozen experience notable color loss. The only Penn/Rocky Mtn trees that exhibited color loss to a similar degree were those placed in the freezer.
The results from this study indicate the importance of genetics and acclimation in the keepability of Douglas-fir Christmas trees. Cut trees of the Rocky Mountain-blue variety grown in Pennsylvania exhibited excellent keepability during our study, due to their ability to acclimate to a rather cold, but not atypical, December. In contrast, moderate temperatures on the West Coast are typically not conducive for acclimation to more severe conditions in the East. Moreover, coastal-green variety trees probably do not have the proper genetic makeup for acclimation to eastern climate, as evidenced by the inability of coastal trees to survive in this region.

The poor performance of Group 2 coastal trees, which were not exposed to their purported low temperature threshold, suggests that the rate of cooling may have been too rapid for the trees (Chastagner, pers. comm.), or that temperatures above those previously reported can harm the coastal genotypes used in this study. While stress factors other than frost or desiccation may have contributed to the rapid deterioration of the coastal trees, it seems clear that frost damage was the primary agent. Based on the results of this study, coastal Douglas-fir may be acceptable for eastern Christmas tree markets only if December climate is unusually mild or steps are taken to protect trees from severe winter conditions.

LITERATURE CITED


