Effect of Cold Storage on Bud Break, Root Regeneration and Shoot Extension of Douglas Fir, Paper Birch and Green Ash[1]

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Abstract

Dormancy level, days to bud break, root regrowth and rate of shoot extension were determined for 18-in seedlings of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), paper birch (*Betula papyrifera* Marsh.) and green ash (*Fraxinus pennsylvanica* Marsh.) subjected to varying durations of cold storage. Douglas fir seedlings did not break bud unless exposed to at least 4 weeks of cold storage, but bud break was unaffected by further time in cold storage. The number of regenerated roots increased with time in cold storage until 12 weeks of chilling and decreased sharply thereafter. Days to bud break of paper birch and green ash decreased as chilling time accumulated. Full dormancy release and maximum root regeneration of paper birch coincided at 10 weeks of chilling. Green ash achieved full dormancy release after 14 weeks of cold storage. The number of roots regenerated increased with cold storage duration for green ash. Shoot extension rate of all species was little affected by chilling duration. Implications for transplanting are discussed.

Index words: *Pseudotsuga menziesii* (Mirb.) Franco, *Betula papyrifera* Marsh., *Fraxinus pennsylvanica* Marsh., chilling, dormancy, transplanting

Significance to the Nursery Industry

Cold storage of fall-dug lining out stock is an important nursery practice since it allows plants to be harvested and stored when plants are dormant, labor is available and weather is permissible. Plants in cold storage can be kept dormant longer than non-stored plants, thus increasing the duration of the shipping period. This also helps nurserymen to better coordinate and ship nursery stock. Growers of ornamental tree species currently have little information concerning the performance of trees that have been held in cold storage. The results of this study show that shoot and root growth of November-dug green ash and paper birch improves with increased time in cold storage. At least 14 and 10 weeks of cold storage for green ash and paper birch, respectively, were most beneficial. Douglas fir needs at least 4 weeks of cold storage before bud break will occur, but post-transplant performance may be poor at all levels of storage.

Introduction

The induction, development and breaking of bud dormancy in trees are complex phenomena consisting of many, often unsynchronized, events (14). Dormancy response to environmental signals can vary greatly within (15) and between (21) species. A general model of dormancy for trees native to cold winter regions is that of a bell shaped curve. A dormant state is initiated after buds are formed during the summer. Intensification of bud dormancy reaches a peak around leaf drop, and the breaking of dormancy is enhanced by chilling temperatures (9). The dormancy period can be divided into three periods: 1) first period of rest, where low temperatures promote the attainment of deeper dormancy, and intermittent warm periods have no deleterious effects on the chilling accumulation; 2) second period of rest, where cold temperatures cause an increased ability to break buds, but warm periods may nullify this effect; and 3) quiescent period, where low temperatures have no effect on rest development and warm periods cause dormancy release and bud break (8).

Chilling accumulation can be quantified by a weighted sum of the number of hours experienced at critical temperatures (chill units) (16). One chill unit is obtained for each hour between 2.5C (36.5F) and 9.1C (48.5F), and one-half chill unit is obtained for an hour either between 1.5C (35F) and 2.4C (36.3F) or between 9.2C (48.6F) and 12.4C (54.3F). Most eastern hardwoods grow roots and shoots rapidly in the spring if exposed to 3000-4000 chill units (5).

The capacity for rapid root regeneration is thought to be the most crucial factor for survival of transplanted trees (3, 20). The effect of cold storage on root regeneration has been studied most extensively for conifers (1, 2, 10), with relatively few reports concerning hardwoods (5, 21). Much work has been reported on western-grown Douglas fir (17, 18), primarily due to its importance as a dominant species in planted forests of the Northwest. Douglas fir is an important species for ornamental planting and Christmas tree production in the Northeast, yet no data are available on the effects of cold storage of eastern-grown stock.

Rapid shoot extension of newly planted liners is desirable, but little information concerning the effect of cold storage on rate of shoot growth of any species has been reported. The purpose of this study was to evaluate the effects of length of cold storage on root regeneration, root growth, dormancy release and shoot extension of eastern-grown Douglas fir, paper birch and green ash.

Materials and Methods

Two hundred and fifty each of 45 cm (18 in) tall, 4-year-old (4x0) Douglas fir (*Pseudotsuga menziesii* (Mirb.)

[1]Received for publication April 30, 1993; in revised form June 16, 1993.
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Franco), 2-year-old (2x0) paper birch (*Betula papyrifera* Marsh.) and 2-year-old (2x0) green ash (*Fraxinus pennsylvanica* Marsh.) were heeled in with moist vermiculite and placed into dark storage at 5C (41F) beginning November 15, 1990. Douglas fir seedlings were obtained from Musser Forests Nursery, Indiana, Pennsylvania, and paper birch and green ash were obtained from Schictel's Nursery, Orchard Park, New York. All seedlings were lifted from the production nursery and shipped just prior to placement in the cold storage facility. Beginning on November 15, and at 14-day intervals until April 10 (10 2-week intervals), 20 seedlings of each of the 3 species were selected at random and planted into #1 (1-gal) containers. Planting media was sterilized, 1:1:1 topsoil-Canadian sphagnum peat-perlite (v:v:v). All potted plants were placed on greenhouse benches at Cornell University, Ithaca, New York, for the duration of the experiment. Daily greenhouse temperatures were maintained at 21C (70F) day and 16C (60F) night, and photoperiod was controlled at 9 hours by light exclusion with opaque cloth. A randomized design was used. At the end of 30 days, media was washed from the roots of 10 plants of each species, and the number of new (white) roots were counted and then dried to a constant weight at 70C (158F). The time to first bud break and the rate of shoot extension were determined on the other 10 plants of each species. Buds were considered broken when leaves could be visibly detected as emerging (approximately 0.5 cm) from parted bud scales. Plants were considered released from dormancy when 50% of buds had broken within a 3-week period (21). Shoot extension of all species was followed until no growth could be detected over a 14-day period, and then observations were terminated. Transformation to natural logarithm was used when appropriate to achieve homogeneity of variance (19).

Results and Discussion

Root initiation (number of new roots) of green ash increased with increasing duration of cold storage (Fig. 1A). Little root initiation occurred after 0 and 2 weeks of chilling. According to the regression model, vigorous root initiation (20 new roots per plant) is apparent when seedlings are exposed to at least 12 weeks of chilling. There is, however, an advantage in additional storage, since root weight (Fig. 1B) and number of new roots continues to increase over a 20-week chilling period.

Time to first bud break decreased with increasing cold storage duration for both green ash and paper birch (Fig. 2 A&B). The overall relationship was similar for both species, except for a small, but significant, quadratic term in the model for green ash. Full dormancy release of green ash occurred after 14 weeks of cold storage (Fig. 3A). This is in close agreement to that reported for white ash (*Fraxinus americana* L.) (22). The relationship between shoot extension rate and time in cold storage of green ash was significant ($p<.0001$), but little variation ($R^2=17.0\%$) was explained by the relationship (data not shown). Dormancy release, root initiation and early root growth all coincide when green ash seedlings are stored for at least 14 weeks under the conditions of this study.

Full dormancy release of paper birch occurred after 10 weeks of cold storage (Fig. 3B). The time required for all replicates of unchilled green ash and paper birch to break bud was considerable. Unchilled green ash required 65 days

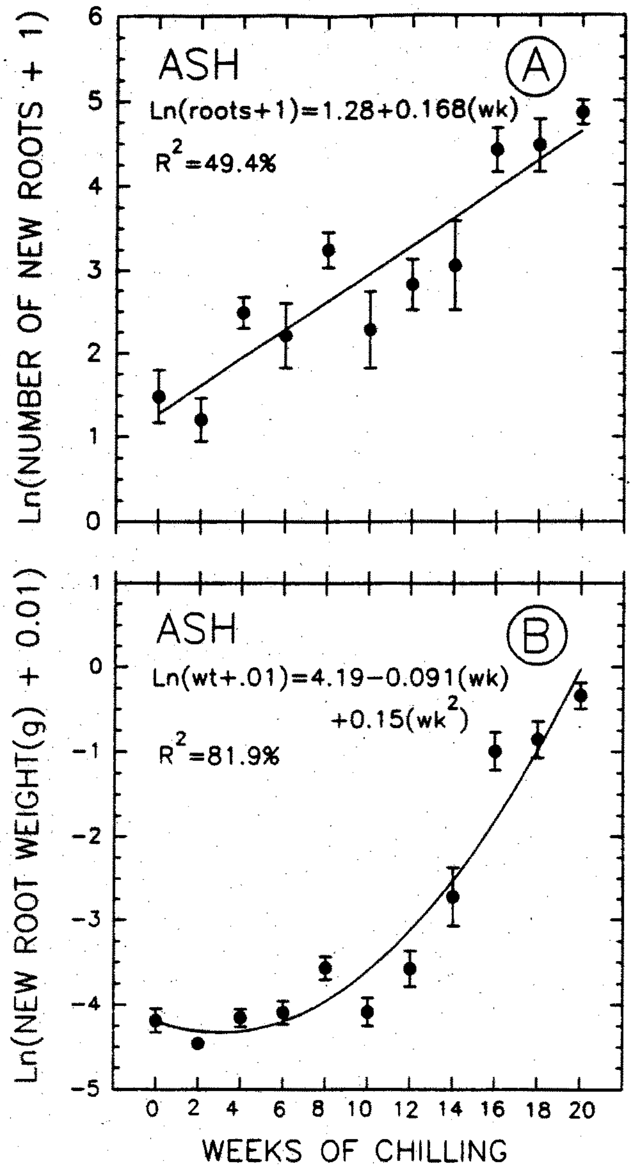

Fig. 1. Relationships between (A) the number of new roots 30 days after transplanting and duration of cold storage and (B) the dry weight of new roots and duration of cold storage for green ash. Data points are means of 10 plants. Error bars represent the standard error of the means.

for all replicates to break buds, and unchilled paper birch required 85 days. Bud break proceeded much more rapidly after only 2 weeks of chilling for paper birch and 4 weeks of chilling for green ash. Rate of shoot extension was also related to time in cold storage ($p<.0001$) (data not shown). However, similar to that for green ash, little variation ($R^2=17.7\%$) was explained by the regression model.

Root initiation of paper birch also increased as time in cold storage increased (Fig. 4A). In contrast to the relationship found for green ash, root initiation increased for up to 10 weeks in storage and was relatively unaffected by chilling thereafter. Bud break and maximum root initiation therefore coincide at 10 weeks of chilling.

Survival was 100%, and no stem dieback occurred for paper birch and green ash at all durations of chilling (data not

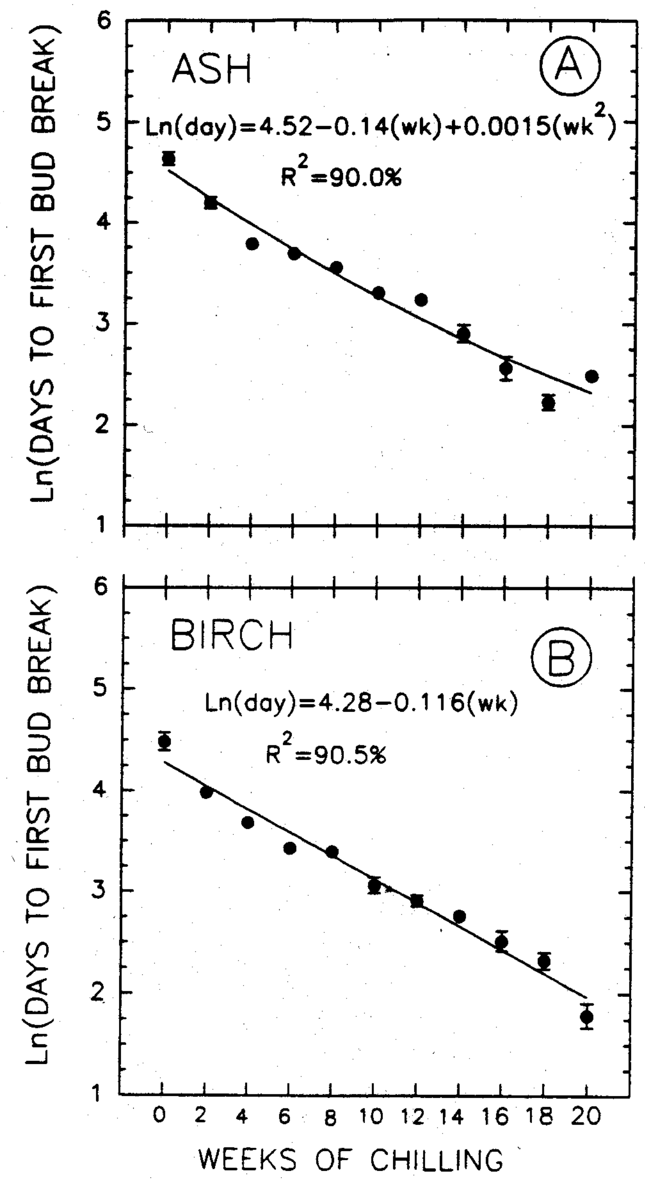

Fig. 2. **Relationships between days to first bud break and duration of cold storage for green ash (A) and paper birch (B). Data points are the means of 10 plants. Error bars represent the standard error of the means.**

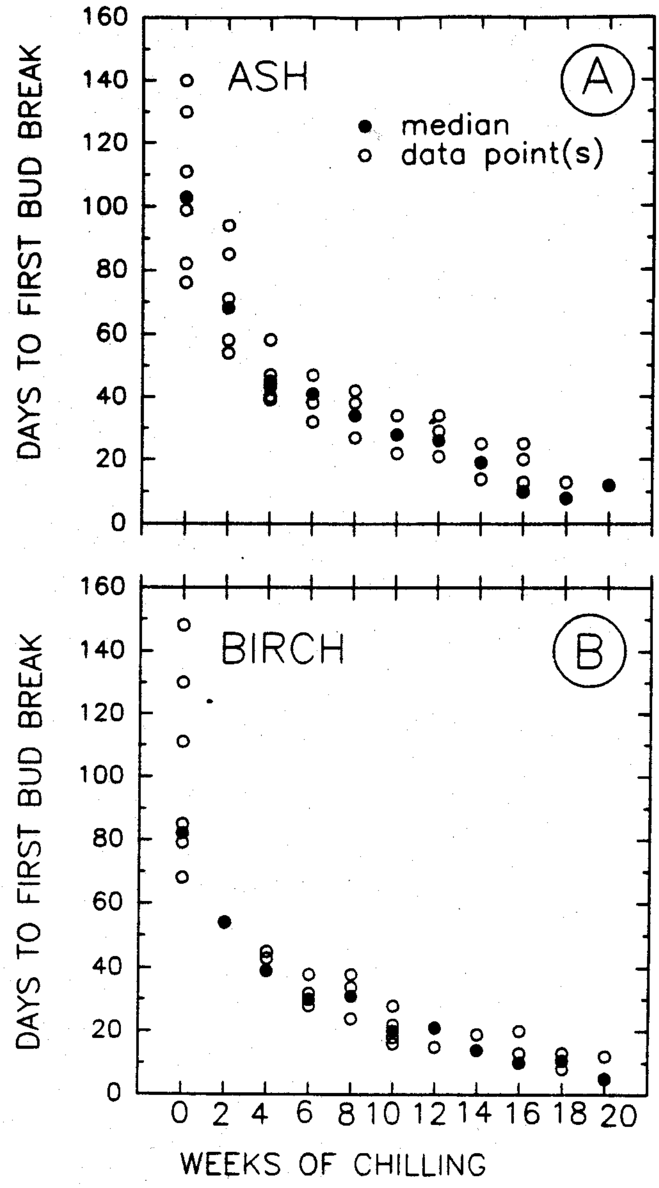

Fig. 3. **Untransformed data showing days to first bud break for each cold storage duration class for green ash (A) and paper birch (B). Some data points are hidden. n=10.**

shown). This contrasts with the findings of Englert *et al.* (4), who found reduced survival and increased stem dieback of paper birch with cold storage. Trees in that study, however, were stored without heeling in, and roots therefore may have been subjected to more desiccation than those in this report. Our study indicates that growers will not improve the root initiation of paper birch by storage longer than 10 weeks. Plants can be stored, however, with no adverse effects for at least 20 weeks. Growth of the new roots (dry weight), nonetheless, was greatest on plants exposed to increasing amounts of chill (Fig. 4B).

Paper birch is reportedly difficult to transplant in the fall in the Northeast, but green ash transplants readily (6). The results of this study negate the hypothesis that the ability to produce roots in the autumn determines the success rate of fall transplanting, since neither green ash nor paper birch produced roots at this time. Few roots were produced on either species until well into January (or at least 8 weeks of chilling), and soil temperatures in the Northeast are well below the limit for root growth by this time. Fall-transplanted green ash and paper birch seedlings must therefore rely on previously produced roots until spring. Root loss at transplanting can be greater than 90% for landscape-sized trees (7). It is interesting to speculate whether the improved transplantability of paper birch in the spring is a function of the newly produced roots. If this is the case, reduced fall transplantability of paper birch compared to green ash could be a result of decreased ability for conductance of water into and through old roots or the stem to the developing buds in the spring. Little or no root growth is evident on trees in Ithaca, New York, before spring bud break (Harris and Bassuk, unpublished data). Water transport into older roots could be impaired by heavy suberization, and the stress of transplanting may result in increased resistance within the root system

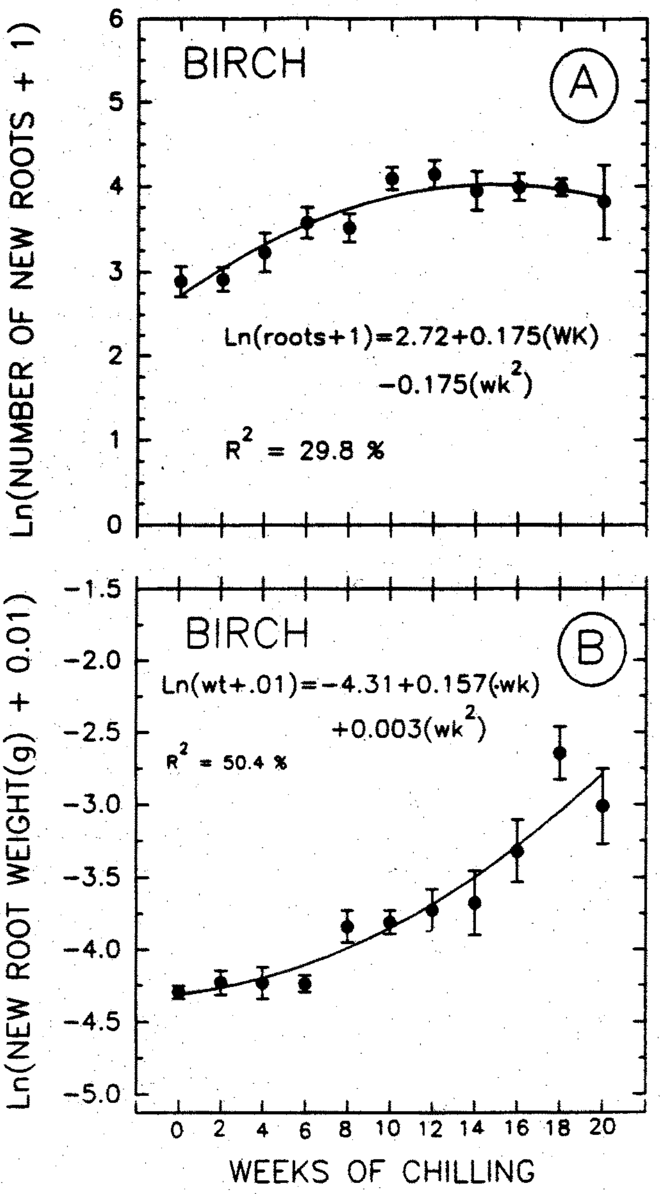

Fig. 4. Relationships between (A) the number of new roots 30 days after transplanting and the duration of cold storage and (B) the dry weight of the new roots and duration of cold storage for paper birch. Data points are the means of 10 plants. Error bars represent the standard error of the means.

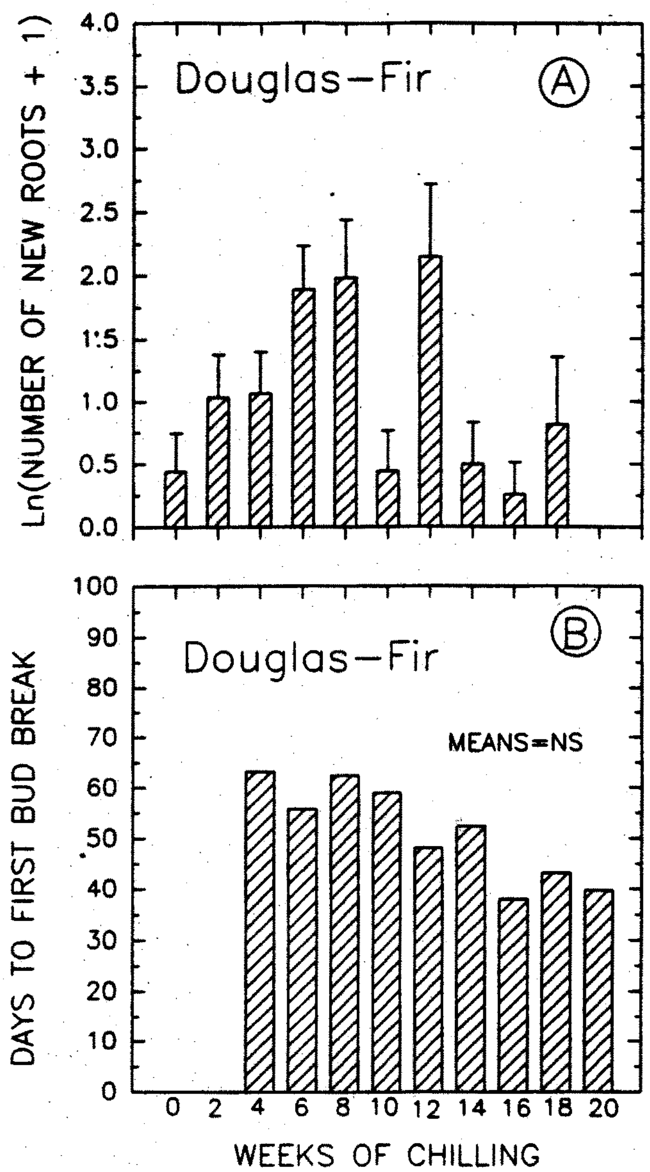

Fig. 5. The number of new roots produced 30 days after transplanting (A) and the days to first bud break (B) for Douglas-fir plants for each cold storage duration class. Error bars represent the standard error of the means. Means are only for plants that produced roots (A) or broke buds (B).

and stem. On the other hand, green ash may not experience such perturbations. Other possible reasons for the lowered spring root regeneration capacity of fall-transplanted paper birch may be a loss of stored carbohydrates in roots removed at digging or a reduced tolerance to winter desiccation.

Root initiation of Douglas fir increased with chilling until 12 weeks and declined thereafter (Fig. 5A). There was very low root regeneration on plants chilled for 10 weeks. The reasons for this are unclear. Douglas fir generally fared poorly in cold storage, however. No plants broke buds after exposure to 0 or 2 weeks of chilling within 200 days of observation (Fig. 5B). Days to first bud break remained outside the time limit for full dormancy release used in this and other (17) studies, and was unaffected by cold storage duration. Survival rate (% of plants that broke buds) was inconsistent for Douglas fir (Fig. 6). Overall coordination of bud break and root regeneration was poor. Although no plants broke buds when exposed to 0 or 2 weeks of chilling, 20% and 60% of plants from those respective groups had grown roots when checked for root initiation 30 days after transplanting. After 18 and 20 weeks of storage, 70% and 30%, respectively, of the seedlings eventually broke buds, but only 20% and 0% had roots. In contrast to green ash and paper birch, no relationship between time in cold storage and extension could be established. Other researchers have also reported poor post-transplant performance of fall-lifted Douglas fir after cold storage (11, 12). Since plants may experience bud dormancy independently of roots (10), it is possible that roots of plants lifted at early dates are still active and are not as hardened off as quiescent roots, particularly when fall temperatures are warm. Roots in this condition may be less resistant to the shock of sudden chilling or

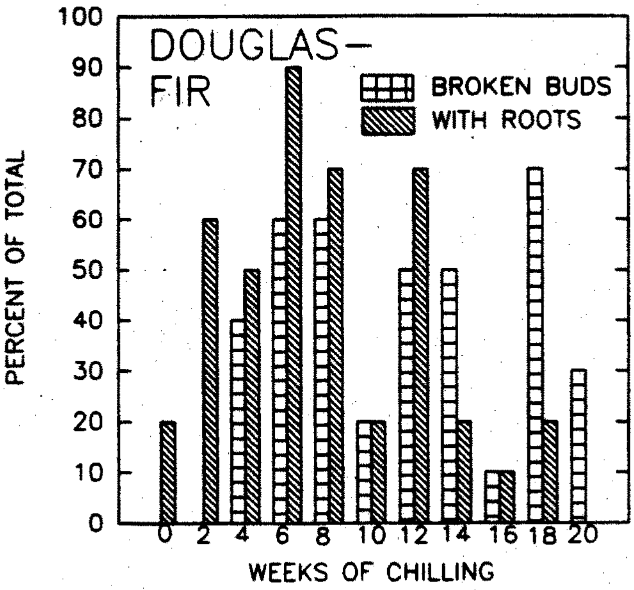

Fig. 6. Percent of total Douglas-fir plants that broke buds over the course of the study, and the percent of total plants that initiated roots 30 days after transplanting for each cold storage duration class.

may be more susceptible to desiccation when placed into cold storage conditions (13). McKay (12) found that fine roots of Douglas fir were less tolerant of cold storage conditions than *Picea sitchensis* (Bong.) (Sitka spruce) or *Larix leptolepis* L. (Japanese larch) at any duration of cold storage. As in our study, Douglas fir seedlings lifted and stored in November performed poorly, particularly at longer storage durations. The results for Douglas fir in our study were unexpected. Additional research is needed on the dynamics of cold storage and transplant performance of Douglas fir in the East.

Fourteen weeks of cold storage conditions for green ash and 10 weeks for paper birch appear to create well correlated post-transplant growth responses under the conditions of this study. This corresponds to approximately 2350 and 1680 chill units acquired after the imposition of cold storage for green ash and paper birch, respectively. These units are somewhat less than the range listed as being most favorable for spring growth of most eastern hardwoods by Farmer (5). However, some units were probably acquired before lifting the plants used in our study. There is little apparent harm in 20 weeks (or approximately 3360 chill units) of cold storage conditions as described in this report for green ash and paper birch. Douglas fir, on the other hand, performed poorly at all intervals of cold storage.

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here may develop growth-limiting container moisture levels earlier than found here, and should benefit more from cyclic microirrigation than reported.

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