SURVIVAL OF WESTERN HEMLOCK SEEDLINGS AFTER COLD STORAGE[1]

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Cold storage of western hemlock seedlings for 1 month in the fall resulted in a low survival after planting. One month of cold storage in December or February was generally beneficial to the seedlings.

The purpose of cold storage is to provide healthy, dormant seedlings at the time they are needed for outplanting. For example, high-elevation sites, which cannot be planted until after bud break in the nursery, will require seedlings that have been held in cold storage to maintain dormancy. Storage will, in essence, lengthen the planting season available for regeneration.

The date of lifting has a major influence on the ability of seedlings to withstand cold storage. Fall-lifting followed by cold storage reduces seedling survival in some species. The date after which seedlings can be safely stored varies both with the species and with the environmental conditions experienced by the seedlings. In the Northwest, cold storage prior to mid-November is generally considered detrimental to Douglas-fir (*3,9*). If Douglas-fir must be lifted and cold stored prior to this time, a daily photoperiod during storage will decrease the loss of seedling vigor. Seedlings stored during the safe period also seem to benefit from a daily photoperiod during storage.

Within the last few years, there has been an active interest in the rapid production of containerized seedlings in greenhouses. Although much research has involved optimum growing conditions and production techniques, little work has been done on the cold storage of containerized seedlings. The objective of this study was to determine if the same storage-dormancy interactions shown for bareroot, Douglas-fir seedlings were also present in containerized western hemlock seedlings.

Methods and Materials

Containerized western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings were obtained from the Crown Zellerbach Wood Nursery in Aurora, Oreg. The containers were molded units of black polyethylene with individual cavities approximately 15 centimeters long and 2 centimeters in diameter with a rooting volume of about 45 cubic centimeters. The rooting medium was a mixture of ground Douglas-fir bark and peat moss. The containers were seeded in late February 1975 with seed from a low-elevation (150 meters) western Oregon source. The seedlings were grown in temperature-controlled greenhouses at the nursery at a density of about 1,000 seedlings per square meter. Seedlings were transferred from the nursery in their original containers to a greenhouse at the Forest Research Laboratory at Corvallis, Oreg., during June 1975. Dormancy was induced with moderate moisture stress, but other greenhouse conditions were maintained at ambient levels. Winter buds began appearing on the seedlings in late August.

On October 1, 1975, the first cold storage treatments began. Two groups of 25 seedlings were moved to a room maintained at 5° C. During cold storage, one group received an 8-hour daily photoperiod, while the other group was stored in darkness. Illumination during the photoperiod was provided by fluorescent tubes at an intensity of about 100 foot-candles. All seedlings were watered once a week to maintain soil moisture during storage. Following 1 month of storage, the seedlings were outplanted in a coldframe maintained under partial shade and received natural overwintering. In the spring of 1976, the seedlings were examined twice a week to determine the date of terminal and lateral bud break and the extent of mortality.

Seedlings not placed in cold storage in October were maintained in an unheated greenhouse with the natural photoperiod until either December 1, 1975, or February 1, 1976. On these dates, the cold storage and outplanting

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procedures used for the October groups were repeated with the single modification that an additional group of 25 seedlings in the February treatment received a 16-hour photoperiod during storage.

The results were subjected to analysis of variance. Significant differences among means were determined by using Duncan's Multiple Range Test.

Results

Criteria used in assessing treatment effects were the dates of terminal and lateral bud break and seedling survival (table 1). Seedlings that received no cold storage, but overwintered under natural conditions in their original containers, had an average date of terminal bud break of April 30. Seedlings planted after December storage had the earliest spring bud break, although it was not significantly earlier than seedlings stored in February. Seedlings stored in October had a much later date of bud break and had the lowest survival. Seedlings planted after December or February storage had excellent survival rates at the end of the growing season. A 16-hour photoperiod during cold storage was found to have a significant effect on accelerating the date of spring bud break, while the difference between seedlings receiving an 8-hour photoperiod and those stored in the dark was not significant. Survival was significantly increased as the photoperiod during storage was lengthened.

The interactions of storage date and photoperiod during storage on bud break and survival are examined in tables 2, 3, and 4. Seedlings that received a daily photoperiod during October storage had earlier bud break than those stored in the dark. Although survival was low for all October-stored seedlings, a photoperiod during storage significantly increased survival. A photoperiod during December or February cold storage generally resulted in seedlings with an earlier date of bud break. These differences, however, were small and may have little practical meaning. Apparently, a short photoperiod during storage was less effective in accelerating bud break after December or February storage. A photoperiod during December or February storage had no significant effect on seedling survival.

Cold storage for 1 month in December or February consistently produced earlier bud break than seedlings that overwintered naturally, regardless of the storage conditions. The date of bud break was between 7 and 10 days earlier than for seedlings that received natural conditions. Dates varied with the treatment received.

Table 1.—*Effect of cold storage date or photoperiod storage on terminal and lateral bud break and survival after outplanting*

Regime	Terminal bud break	Lateral bud break	Survival percent
	- - - - Days after April 1- - - -		
No storage	30	28	100
DATE OF STORAGE			
October	35[a*]	34[a]	35[a]
December	20[b]	18[b]	96[b]
February	22[b]	21[b]	100[b]
PHOTOPERIOD			
Dark	27[a]	26[a]	71[a]
8-hour	25[a]	24[a]	83[b]
16-hour	20[b]	20[b]	100[c]

*For either storage date or photoperiod, values within each column followed by the same letter do not differ significantly (P = 0.05).

Table 2.—*Effect of photoperiod during various storage dates on number of days after April 1 to terminal bud break*

	Date		
Photo-period	Oc-tober	De-cember	Feb-ruary
Dark	37[a]*	20[b]	23[c]
8-hour	32[d]	20[b]	22[c]
16-hour	—	—	20[b]

*Values followed by the same letter do not differ significantly (P = 0.05).

Table **3.**—*Effect of photoperiod during various storage dates on number of days after April 1 to lateral bud break*

	Date		
Photo-period	Oc-tober	De-cember	Feb-ruary
Dark	36[a]*	19[bc]	23[d]
8-hour	33[a]	17[b]	21[cd]
16-hour	—	—	20[c]

*Values followed by the same letter do not differ significantly (P = 0.05).

Table 4.—*Effect of photoperiod during various storage dates on survival (percent)*

	Date		
Photo-period	Oc-tober	De-cember	Feb-ruary
Dark	16[a]*	98[c]	100[c]
8-hour	54[b]	94[c]	100[c]
16-hour	—	—	100[c]

*Values followed by the same letter do not differ significantly (P = 0.05).

Discussion

Many findings from this study compare favorably with prior data on western hemlock as well as other species. However, the bulk of the literature relating to cold storage of seedlings has dealt with bareroot stock and few data are available for containerized seedlings. Brown (*1*) found that the root regenerating potential of either bareroot nursery seedlings or container-grown seedlings of western hemlock was not deleteriously affected by 4 weeks of dark, cold storage in the fall. After transplanting in the field, however, seedlings stored in October had a high mortality rate. Seedlings lifted and stored after December had good survival rates. Brown's findings on the date of lifting and storage as it affected survival were very similar to those that I observed. Since fall cold storage of western hemlock is not detrimental to the seedlings' root regenerating potential, it is clear that survival is not merely based on the root regenerating potential at the time of lifting. It may be that the rapid temperature change experienced by the roots of seedlings moved from a greenhouse into a cold chamber is responsible for the adverse effects of cold storage in the fall.

My results show that a daily photoperiod during fall storage of western hemlock is beneficial. While seedlings receiving a photoperiod during fall storage still had low survival, it was considerably greater than for seedlings receiving dark storage. A daily photoperiod during fall cold storage of Douglas-fir seedlings has previously been found to increase that species' survival after planting (*3,6*). The reason for the effectiveness of a daily photoperiod in increasing survival is still unclear. The light intensity used in all studies was relatively low and would seem to have had little effect on seedling photosynthesis during storage.

From an operational standpoint, western hemlock seedlings will require the same precautions relating to cold storage found necessary for Douglas-fir. Proper storage conditions, such as appropriate temperature, soil moisture, and humidity, are similar for the two species and must be present to ensure quality seedlings at the time of planting (*2,4*). My data show that if fall planting of western hemlock is necessary, the stock should not receive cold storage prior to outplanting. Cold storage of containerized western hemlock seedlings after the beginning of December will have no detrimental effects and will, in fact, produce seedlings with early, vigorous spring growth. Winter storage can provide a valuable technique in stock production for planting on sites that experience early moisture stress, since early spring bud break will give the seedlings a better chance of survival under these circumstances. Seedlings receiving a 16-hour photoperiod during February storage had the earliest bud break for seedlings stored at that time. However, if cold storage is used to prolong the date of bud break, long photoperiods during storage should be avoided since this may lead to bud break of the seedlings while in cold storage, as has been shown for Douglas-fir (*5*).

Cold storage during the late winter may be especially helpful if seedlings have received insufficient natural chilling in a greenhouse. Work with Douglas-fir has shown that cold storage at 2° C is effective in fulfilling the chilling requirements of that species (*8*). This is also true for western hemlock (*7*).

Literature Cited

1. Brown, C. J.
   1976. Patterns of growth and seasonal changes in the concentrations of abscisic acid and indole acetic acid in roots of western hemlock. M.S. Thesis. Oreg. State Univ., Corvallis. 97 p.
2. Brown, R. M.
   1973. Cold storage of forest plants. For. Comm. For. Rec. 88, 19 p.
3. Hermann, R. K., D. P. Lavender, and J. B. Zaerr.
   1972. Lifting and storing western conifer seedlings. Oreg. State Univ. For. Res. Lab. Res. Pap. 17. 8 p.
4. Hocking, D., and R. D. Nyland.
   1971. Cold storage of coniferous seedlings. State Univ. of N.Y. Appl. For. Res. Inst., Res. Rep. No. 6. 70 p.
5. Lavender, D. P.
   1978. Bud activity of Douglas-fir seedlings receiving different photoperiods in cold storage. In Proc. 5th North Am. For. Biol. Workshop, Gainesville, Fla. [In press.]
6. Lavender, D. P., and P. F. Wareing.
   1972. Effects of daylength and chilling on the response of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings to root damage and storage. New Phytol. 71: 1055-1067.
7. Nelson, E. A.
   1979. The chilling requirement of western hemlock seedlings. For. Sci. [In press].
8. Van den Driessche, R.
   1977. Survival of coastal and interior Douglas-fir seedlings after storage at different temperatures, and effectiveness of cold storage in satisfying chilling requirements. Can. J. For. Res. 7:125-131.
9. Winjum, J. K.
   1963. Effect of lifting date and storage on 2-0 Douglas-fir and noble fir. J. For. 61:648-654.