RESULTS OF FALL LIFTING AND OVERWINTER STORAGE TRIALS AT THE COEUR D'ALENE NURSERY

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Early spring lifting of large quantities of conifer planting stock in northern temperate zone nurseries is often fraught with difficulties. The plants, with their chilling requirements satisfied, are ready to respond to warm spring temperatures and initiate rapid growth. Warming trends can be gradual, sporadic, or rapid and lifting operations can be delayed by unfavorable weather. Time, personnel, machinery, and space impose additional limits to the lifting, sorting, and packing operation. Delays in lifting beyond a certain point in the dormancy breaking process are apt to cause undesirable stresses in the plants, resulting in decreased survival and growth potential. The Coeur d'Alene Nursery has had difficulty in lifting all of its stock before the breaking of dormancy. Since the capacity of the nursery has been increased, the problem has become critical. In 1971 studies of fall lifting and overwinter storage as a supplement to conventional spring lifting were initiated.

Encouraged by results from Europe, Canada, and the northeastern United States (Hocking and Nyland 1971), investigations began with overwinter storage in 1971-72. The stored stock was planted at the nursery where it was subjected to three semicontrolled moisture stress regimens. These tests were encouraging and laid the groundwork for a small scale field trial in 1972-73 (McDonald 1975; McDonald, Boyd, and Sears in preparation). Since then, the 1972-73 field test trees (survival and height) have been remeasured and a larger "pilot scale" field test was established in 1974-75.

In 1976, expansion of facilities at the Coeur d'Alene Nursery included provision for subfreezing storage temperatures. Fir millon trees were lifted in the fall of 1976, stored overwinter at -2 C (28 F), and field planted during the spring of 1977. This report will give (1) the results of field planting tests (survival and growth), (2) observations concerning the operational phase of the program, and (3) recommendations for the use of overwinter subfreezing storage.

1972-1973 FIELD TRIALS

Methods

Engelmann spruce (2-0), lodgepole pine (2-0), and western larch (1-0) stock were (1) fall lifted (November 27-December 1, 1972) and stored at -2 C (28 F+1); (2) spring lifted (March 19, 1973) and stored at 1 C (33 F), and (3) freshly lifted 2-3 days prior to planting. Trees from each storage regimen were planted on April 18, May 9 and 30, and June 20, 1973. Trees were planted on a clearcut area on the Coeur d'Alene National Forest that had been prescribed burned the previous fall. The field planting was done in a randomized block design with two replications. Each treatment unit consisted of 50 trees.

Survival was measured after the first and third growing seasons, and height measurements were taken on every third tree at the end of the third growing season. Third-year results are reported here (tables 1, 2, and 3).

Results

Western larch.--Over all planting dates, the survival of fall lifted stock was significantly better (71 percent) than either fresh lifted or spring lifted and stored stock (62 percent) (table 1). Planting date had the greatest effect on survival. Delays in planting resulted in poorer survival. The relatively poor survival for the May 9 planting may be due to an unusually warm, dry period of 13 days following planting.

After three years growth, fall-lifted stock was consistently taller than spring-lifted stock (84 cm vs. 76 cm and 69 cm; 33 inches vs. 30 inches and 27 inches), regardless of planting date (table 2). As with survival, early planting produced taller trees for all of the lifting-storage treatments.

Combining survival and average third-year height (third-year stem length production per 100 planted trees) (table 3) shows the superiority, over all planting dates, of fall lifted -2 C(28 F) storage treatement for larch (61.3 m (201.1 ft) of stem/100 planted trees vs. 49.4 m (162.1 ft) and 43.0 m (141.1 ft) for spring lifted and fresh lifted stock, respectively).

Lodgepole pine.--Survival of lodgepole pine for all planting dates after 3 years was equivalent for the fall lifting and the spring lifted and stored stock (81 percent and 82 percent) (table 1). Except for the first planting, survival of fresh lifted stock was inferior. Survival over all storage treatments remained high for the first three planting dates (74-91 percent) but declined on the June 20 planting to 61 percent.

Over all planting dates there was no significant difference in third-year height between fall and spring lifted stock, nor between fall

Table 1.--Effects of lifting and storage treatments and planting date on third-year survival of field planted western larch, lodgepole pine, and Engelmann spruce, 1972-72 field trials 1/

Planting date	Larch			Pine			Spruce		
	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)
	- - - - - - - - - - -			- - - Percent - - -			- - - - - - - - - - -		
4/18	80	87	94	92	92	87	71	84	91
5/9	54	75	72	66	78	77	65	70	51
5/30	63	54	84	65	90	96	29	49	55
6/20	49	34	33	51	70	63	34	56	46
$\bar{x}$ all dates	62 b 2/	62 b	71 a	69 b	82 a	81 a	50 b	65 a	61 a

1/ Basis: Two replications of 50 trees for each species-storage regimen-planting date combination.

2/ Within a species, average survival values for storage regimens followed by the same letter are not significantly different at the 0.05% level.

Table 2.--Effects of lifting and storage treatments and planting date on third-year height of field planted western larch, lodgepole pine, and Engelmann spruce, 1972-73 field trials-1/

Planting date	Larch			Pine			Spruce		
	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)
	Centimeters (Inches)								
4/18	69 (27)	84 (33)	91 (36)	56 (22)	64 (25)	53 (21)	38 (15)	46 (18)	46 (18)
5/9	86 (34)	91 (36)	94 (37)	48 (19)	64 (25)	56 (22)	33 (13)	41 (16)	36 (14)
5/30	66 (26)	71 (28)	86 (34)	53 (21)	61 (24)	61 (21)	38 (15)	36 (14)	41 (16)
6/20	56 (22)	53 (21)	66 (26)	43 (17)	46 (18)	43 (17)	36 (14)	36 (14)	27 (11)
$\bar{x}$ all dates	69 b 2/ (27)	76 b (30)	84 a (33)	51 b (20)	58 a (23)	53ab (21)	36 a (14)	41 a (16)	38a (15)

1/ Basis: Two replications of 50 trees for each species-storage regimen-planting date combination.

2/ Within a species, average height values for storage regimens followed by the same letter are not significantly different at the 0.05% level.

Table 3.--Effects of lifting and storage treatments and planting date on the third-year stem production of field planted western larch[1]/lodgepole pine, and Engelmann spruce, 1972-73 field trials-

Planting date	Larch			Pine			Spruce		
	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)	Fresh	Spring 1°C (33°F)	Fall -2°C (28°F)
	Meters (feet)/100 planted trees								
4/18	54.8 (179.8)	72.4 (237.5)	84.9 (278.6)	50.8 (166.7)	57.8 (189.6)	49.1 (161.1)	27.2 (189.2)	37.8 (124.0)	41.1 (134.8)
5/9	47.7 (156.5)	68.0 (223.1)	68.0 (223.1)	31.3 (102.7)	49.2 (161.4)	43.2 (141.7)	21.5 (70.5)	27.7 (90.9)	18.3 (60.0)
5/30	41.7 (136.8)	38.9 (127.6)	69.9 (228.4)	33.3 (109.3)	55.7 (182.8)	58.0 (190.3)	10.6 (34.8)	18.0 (59.1)	21.9 (71.8)
6/20	27.5 (90.2)	17.9 (58.7)	22.1 (72.5)	21.4 (70.2)	32.5 (106.6)	27.2 (89.2)	12.0 (39.4)	19.7 (64.6)	12.6 (41.3)
$\bar{x}$ all dates	43.0b[2]/ (141.1)	49.4b (162.1)	61.3a (20.10)	34.1b (111.9)	48.8a (160.1)	44.2a (145.0)	18.0b (59.1)	25.9a (85.0)	23.5ab (77.1)

[1]/ Basis: Two replications of 50 trees for each species-storage regimen-planting date combination.

[2]/ Within a species, average stem production values for storage regimens followed by the same letter are not significantly different at the 0.05% level.

and fresh stock (table 3). Height was equivalent for the first three planting dates and significantly less for the June 20 planting.

Stem production was equivalent for fall and spring lifted stock (44.2 m (145.0 ft) and 48.8 m (160.1 ft)) and significantly less for fresh stock (34.1 m; 111.9 ft) (table 3).

Engelmann spruce.--Third year survival of spruce was equivalent for fall and spring lifted stock (61 percent vs. 65 percent) over all planting dates and better than fresh stock (50 percent) (table 1). Survival declined rapidly with delays in planting. Survival of the April 18 planting was significantly higher (82 percent) than that of the May 9 planting (62 percent) which was in turn higher than that of the two later plantings (44 percent and 45 percent).

There were no important differences in third-year height between the lifting-storage treatments (table 2). Average third-year height of trees planted on April 18 was significantly greater (43.2 cm; 17 inches) than those planted on June 20 (33 cm; 13 inches).

Third-year average stem production over all planting dates was best for spring lifted stock (26 m; 85 feet) but not significantly greater than for fall lifted stock (23 m; 77 feet) (table 3). Fresh lifted stock produced significantly less stem length/100 planted trees (18 m; 59 feet). The earliest planting, regardless of treatment, produced significantly more stem length (35 m; 116 feet) than any of the other planting dates (15 m (49 feet) to 23 m (74 feet)).

1974-75 PILOT FIELD TRIAL

Methods

Engelmann spruce (2-0), Douglas-fir (2-0), grand fir (2-0), western larch (1-0), and ponderosa pine (2-0) stock was lifted and stored as follows:

1. Fall lifted (November 22-25, 1974) and stored overwinter at -2°C (28±1°F) in poly-kraft bags.

2. Fall lifted and stored overwinter at 1°C (33±2°F) in open bales.

3. Fall lifted and stored overwinter at 1°C (33±2°F) in poly-kraft bags.

4. Spring lifted (March 13-20, 1975) and stored at 1°C (33±2°F) in poly-kraft bags.

All fall lifted stock had shown a dormant trace on the oscilloscope (Ferguson, Ryker, and Ballard 1975) for at least 10 days prior to lifting. Spring lifted stock was also fully dormant with no evidence of root growth or an active trace on the oscilloscope.

Trees were planted between April 30 and May 2, 1975 in rows of 20 trees. Planting followed a randomized block design with ten replications. Spruce and grand fir were planted together (alternate rows) on a gentle north facing slope typical of the hemlock/pachistima habitat type. Douglas-fir and larch were planted together on a gentle northwest facing slope of the same habitat type. Ponderosa pine was planted on a drier west facing slope (cedar/pachistima habitat type) just around the hill from the Douglas-fir and larch. The soils on this site contained much more rock and were fairly difficult to plant. Old ponderosa stumps were in evidence.

Results

Survival and height growth have been measured annually for 3 years. Very little mortality was observed beyond the first growing season. Comparisons of first-year survival, third-year height, and the total stem length per 100 planted trees (third-year survival percentage x third-year height) are presented for each species as follows (tables 4, 5, and 6):

Table 4.--Effect of lifting and storage regimens on the first-year survival of field planted conifers, 1975-76 pilot planting[1/]

Treatment	Species				
	Engelmann spruce	Douglas-fir	Grand fir	Western larch	Ponderosa pine
	- - - - - - - - - - - - - - Percent - - - - - - - - - - - - - -				
Spring lift 33°F, bags	87 a[2/]	78	91 a	91 a	87 a
Fall lift 28°F, bags	88 a	90 a	88 a	89 a	86 a
Fall lift 33°F bale	81 a	61 b	76 b	--	84 a
Fall lift 33°F, bags	87 a	73 b	80 b	96 a	84 a

[1/] Basis: 10 replications of each species-treatment combination in 20-tree rows (800 trees of each species).

[2/] Within a species, survival values followed by the same letter are not significantly different at the 0.05% level.

Table 5.--Effect of lifting and storage regimens on 49 third-year height of planted conifers, 1975-76 pilot planting-!

Treatment	Species				
	Engelmann spruce	Douglas-fir	Grand fir	Western larch	Ponderosa pine
	Centimeters (Inches)				
Spring lift 33°F, bags	44 a (17)	53 a (21)	32 a (13)	91 a (36)	41 a (16)
Fall lift 28°F, bags	46 a (18)	50 a (20)	27 a (11)	87 a (34)	41 a (16)
Fall lift 33°F, bale	40 b (16)	45 a (18)	29 a (11)	--	37 a (15)
Fall lift 33°F, bags	42ab (17)	44 a (17)	29 a (11)	88 a (35)	38 a (15)

1/ Based on sample measurements of every other live tree in 5 of the 10 replications.

2/ Within a species, height values followed by same letter are not significantly different at the 0.05% level.

Table 6.--Effect of lifting and storage regimens on the third-year stem production of planted conifers, 1975-76 pilot planting1/

Treatment	Species				
	Engelmann spruce	Douglas-fir	Grand fir	Western larch	Ponderosa pine
	Meters (feet)/100 planted trees				
Spring lift 33°F, bags	36.4 a2/ (119.4)	42.7 a (140.1)	27.9 a (91.50	80.5 a (264.1)	35.3 a (115.8)
Fall lift 28°F, bags	36.6 a (120.1)	42.3 a (138.8)	22.0 b (72.2)	72.3 a (237.2)	33.3 a (109.2)
Fall lift 33°F, bale	30.3 a (99.4)	34.5 a (113.2)	19.5 b (64.0)	--	30.8 a (101.1)
Fall lift, 33°F, bag	35.4 a (116.1)	29.5 a (96.8)	23.6 ab (77.4)	83.9 a (275.3)	32.6 a (107.0)

1/ Based on the third-year survival of 5 replications and the average height of every other live tree in the same 5 replications.

2/ Within a species, average stem production values followed by same letter are not significantly different at the 0.05% level.

Engelmann spruce.--Spruce survival for all treatments averaged 86 percent, ranging from 81 percent to 88 percent. None of the differences can be attributed to lifting and storage treatments (table 4). Average height at the end of the third growing season was 43 cm (17 inches) with no significant differences between treatments (table 5). Stem lengths produced per 100 planted trees were nearly identical for spring lifted trees and those fall lifted and stored in poly-kraft bags (35.4 m (116.1 ft) and 36.6 m (120.1 ft)) (table 6). The production of 30.3 m (99.4 ft) for fall lifted trees stored at 1 C (33 F) in open bales was not significantly lower than other treatments. The spruce is growing well with good color and is quite vigorous except where planted in skid roads that were seeded with domestic grasses. Some minor spring frost damage was observed.

Douglas-fir.--Survival of Douglas-fir lifted in the fall and stored at -2 C (28°F) was superior (significant at the 0.01 percent level) to the survival of trees in the other lifting-storage regimens (90 percent vs. 61-78 percent) (table 4). Of the trees lifted in the fall, 1 C (33 F) storage in open bales resulted in the poorest survival. Survival of trees lifted in the fall and stored at -2 C (28 F) exceeded that of conventional spring lifted stock by 18 percentage points. Growth of surviving trees averaged 48 cm (19 inches) and ranged from 44 cm (17 inches) to 53 cm (21 inches) with no significant treatment differences (table 5). Stem production per 100 planted trees at the end of the third growing season was nearly the same for spring lifted stock and that which was fall lifted and stored at -2 C (28 F) (42-43 m; 137.8-141.1 ft) (table 6). Although production of the fall lifted trees stored at 1 C (33 F) in bales and bags was considerably less, wide variation in results rendered the differences nonsignificant.

Growth differences of Douglas-fir were confounded with snowshoe hare damage. Only those replications hich were the least damaged were measured for growth data (5 of the 10 replications).

Grand fir.--Survival of grand fir spring lifted and fall lifted and stored at -2 C (28 F) was better (91 percent and 88 percent) than in either of the other fall lifting treatments (76-80 percent) (table 4). Nearly all of the grand fir were damaged by late spring frosts after bud burst. Very few of the trees escaped damage in at least one of the three growing seasons. Consequently, results of any height growth analysis are questionable (tables 5 and 6).

Western larch.--Neither survival, third-year height, nor stem production/100 planted trees was significantly influenced by the tested lifting and storage regimens of larch (table 4). However, larch which was fall lifted and stored at 1 C (33 F) in bales was in such poor condition that it was not planted. Survival averaged 91 percent (87-95 percent), third year height (table 5) averaged 89 cm (35 inches) and stem production averaged 79 m (259.2 ft)/100 planted trees (table 6). Surviving larch were generally vigorous and not damaged by hares which damaged

many interplanted Douglas-fir trees. One-third of the measured larch trees were over 1 m (3.3 ft) tall.

Ponderosa pine.--Survival of ponderosa pine after 3 years averaged 85 percent (81 percent to 87 percent) with no differences attributable to the lifting and storage treatments (table 4). Height at the end of the third growing season was essentially equal for all treatments as well (37-41 cm; 15-16 inches) (table 5). Stem production averaged 33 m (108 ft) per 100 planted trees with no significant treatment differences (table 6). Trees were vigorous. Minor hare damage was observed.

1976-77 OPERATIONAL EXPERIENCE

Beginning with the first week of November 1976, 5 million trees were lifted at the Coeur d'Alene Nursery, packaged in poly-lined kraft bags, preconditioned for two weeks at 1 C (33-34 F), and stored until spring at -2 C (28 F). Species lifted were ponderosa pine, Douglas-fir, Engelmann spruce, grand fir, western larch, and lodgepole pine. Fall lifting accounted for about 45 percent of the trees planted in the spring of 1977. It was intended that all of these trees would be shipped to the users early in the spring and stored in snow caches for a month or more prior to planting. The scarcity of snow made this impossible in some instances. As a result, some trees were shipped to the field during the planting season.

Fall of 1977 survival reports indicate that success was very good. All species except ponderosa pine have shown excellent survival and first-year growth. Several lots of ponderosa pine appeared to have been stressed. Ponderosa pine was the first species lifted in 1976. Although a dormant oscilloscope trace was obtained, it is highly possible that some lots were lifted a bit early and were not quite dormant enough. The pine was lifted approximately 2 weeks ahead of dates of lifting in previous tests.

CONCLUSIONS AND RECOMMENDATIONS

Over a range of spring planting dates, conifer stock lifted the previous fall (November) and stored overwinter in polyethlyene-lined kraft bags at -2 C (28+2 F) has survived and grown as well as stock lifted in the late winter or early spring and stored at 1 C (33+2 F). While overwinter storage at 1 C (33 F) provided a satisfactory regimen with most species, it is not recommended due to the potential hazards involved with slight changes in temperature due to improper storage or equipment problems. Pending more definitive studies, it is recommended that trees not be lifted until they are fully dormant as indicated by oscilloscope trace analysis. Region 1 guides state that fall lifting should generally begin 1-2 weeks after the square wave is obtained or anytime after November 15 at Coeur d'Alene.

Provisions should be made for slowly thawing packages of trees prior to shipment. In Region 1, we ship stock to the Districts for snow cache storage in late January or February. Otherwise, the stock is shipped just prior to planting (2 weeks ahead of planting at most). In any case, our desire is to increase tree box temperatures to 2 C (34-35 F), just prior to shipment. At the nursery the thawing process may take several weeks of 5-7 C (40-45 F) temperatures. Packages of trees from subfreezing storage should not be subjected to high temperatures to promote rapid thawing.

It is apparent from our investigations so far that two areas for further work stand out. One is need for an accurate assessment for determining the time that fall lifting can be started. The oscilloscope is a good tool, but its use remains an art, not an exact science. For this reason, we do not recommend lifting until a dormant trace is observed for at least a week. We have no evidence on what the effect of a lifting date prior to a dormant trace would be. We may be able to lift earlier for some species.

The other major area of needed work is in storage temperatures in the interphases from the nursery bed to the freezer and from the freezer prior to shipment. How long should the interphase period be and at what temperature?

We are confident that fall lifting and overwinter storage is a valid operational procedure at the Coeur d'Alene Nursery. Our results indicate that overwinter storage is at least as feasible as the conventional spring lift. Fall lifted stock has performed equally or better than spring lifted stock.

The greatest advantage to fall lifting is the reduction of the pressure on the spring lifting operation to lift the entire amount of stock to be shipped. With the spring program reduced, the job can be done sooner with less danger of having to lift trees after they have commenced growth.

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