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Effect of Jellyrolling and Acclimatization on Survival and Height Growth of Conifer Seedlings

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Abstract

Field tests with control (C), root-dipped (D), jellyrolled (J), and jellyrolled and acclimatized (J + A) bare-root seedlings were conducted at 14 sites in Oregon and Washington in 1984. Nine tests were conducted with ponderosa pine, four with Douglas-fir, and one with lodgepole pine. A separate test with ponderosa pine and Douglas-fir was conducted in Washington in 1983.

In the 1984 test, average values of survival for ponderosa pine for the C, D, J, and J + A treatments were 82, 86, 85, and 87 percent, respectively. The increases in height were 16, 18, 17, and 15 percent, respectively. Survival of the J + A seedlings was significantly higher than that of C seedlings, but other differences among treatments for survival or growth were not significant. For Douglas-fir, average values of survival for the C, D, J and J + A treatments were 77, 72, 74, and 70 percent, respectively; height growth was 18, 19, 17, and 18 percent, respectively, with no significant differences. Survival of lodgepole pine was 99 percent for all treatments, and height growth ranged from 28 to 34 percent.

In the 1983 test in Washington, survival of ponderosa pine ranged from 70 percent for C seedlings to 80 percent for J + A seedlings, but results were not consistent among the three sites and therefore not conclusive. Height growth in pine ranged from 34 (J) to 41 (D) percent. Survival of fir seedlings ranged from 97 to 100 percent, and growth from 21 to 23 percent.

Seedling moisture stresses prior to planting were significantly higher in J + A fir and pine seedlings than in C, D, or J seedlings in two cases, and higher than D or J seedlings in another. Control seedlings developed significantly higher moisture stresses in a planting bag than did D, J, or J + A seedlings that developed similar stresses. Collectively, the results indicated that there is no advantage in survival, height growth, or moisture stress from jellyrolling or acclimatizing seedlings as compared to root dipping the seedlings.

Keywords: Seedling survival, increments (height), seedling growth, bare root nursery stock.

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Introduction

Exposure of roots of bareroot conifer seedlings to drying conditions during planting decreases survival (Feret and others 1985; Hermann 1962, 1967), and regeneration guides recommend that exposure of roots be kept to a minimum (Cleary and others 1978, Dahlgreen 1976). Attempts to minimize root desiccation have included dipping roots in water (Mullin 1971), in sodium alginate solutions (Owston and Stein 1972), in vermiculite slurries,[1/] and in clay slurries (Dierauf and Marler 1969, Owston and Stein 1972). More recently, jellyrolling has been recommended (Dahlgreen 1976). Jellyrolling is a preplanting treatment that involves dipping roots of seedlings in a vermiculite-water slurry and wrapping the roots in wet burlap to form a roll. Usually the seedlings are wrapped 50 to a bundle 1 or 2 days prior to outplanting. With increased emphasis on obtaining better survival and growth in planted seedlings, jellyrolling is increasingly common in the Pacific Northwest. The technique is described in a recent publication on regeneration (Lotan and Perry 1983) and in USDA Forest Service planting specifications. A recent Extension Service bulletin (Cleary and DeYoe 1982) suggests that jellyrolling is a good option when seedlings are planted in extremely hot and dry conditions. One large forest nursery offers jellyrolling as a service at the nursery prior to shipping seedlings.

Dahlgreen (1976) proposed that seedlings be both jellyrolled and acclimatized. The objective of jellyrolling is to keep seedlings wet during handling and planting, and to minimize damage to roots caused by handling during planting. An additional benefit is that flecks of vermiculite adhering to roots aid in distinguishing seedling roots from other woody roots when root orientation is checked during planting operations. Some foresters feel that the whole jellyrolling procedure results in more careful handling and planting of seedlings. Acclimatization involves keeping jellyrolled seedlings in a shelter, such as a tent or shed, for 24 to 48 hours to allow temperature adjustment to the field environment.

Currently, foresters jellyroll seedlings in one of two ways. In some cases, seedlings are jellyrolled and then kept in cold storage until they are planted 1 or 2 days later. In other cases, after jellyrolling, seedlings are acclimatized for 1 or 2 days in a tent or shed located in the field or near the seedling storage facility.

[1/] Unpublished report, 1975, "Preplanting Root Dip," by R.A. Ryker, on file at U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 324-25th Street, Ogden, UT 84401.

Few data are available on the effects of jellyrolling or acclimatization on survival or growth of conifer seedlings. I know of only two field tests. One involved plantings of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) seedlings in eastern Oregon. Jellyrolling did not increase survival, but did increase height growth of ponderosa pine by 15 percent.[2/] The other study—done in Idaho and involving nearly 110,000 seedlings—consisted of four field trials with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and one with ponderosa pine.[3/] The test included jellyrolling and root dipping in water. None of the treatments increased survival or growth significantly; however, conditions were cool and moist during planting and this may not have provided appropriate conditions for testing the technique.

Even less is known about effects of acclimatization. Changes in physiological functioning of seedlings following removal from cold storage have not been extensively studied, so there is little physiological basis on which to judge the value of acclimatization. In an administrative study conducted in the Boise National Forest in Idaho in 1979[4/] there was little difference in first-year survival or growth of ponderosa pine seedlings acclimatized for 1 to 5 days, but survival and growth decreased drastically after a 10-day treatment.

Dipping roots of bareroot seedlings in a peat moss-water mixture at the planting site just prior to planting to keep roots wet is common during many planting operations. In a review of factors affecting performance of planted seedlings, Chavasse (1980) states that moistening roots of coniferous stock before planting improves survival and growth. Also, Mullin (1971) found dipping roots in water to be beneficial, but in that study seedlings were root-dipped immediately after lifting in the nursery. In a recent study with jack pine (*Pinus banksiana* Lamb.) seedlings in Michigan (Belli and Dickman 1985), seedlings were sprayed with water, sealed in plastic-lined bags, and stored for 39 hours at 4.5 °C. The roots of both sprayed and unsprayed (control) seedlings then were soaked for 30 minutes in tapwater immediately before planting. Neither the spray nor soak treatment had any significant effect on seedling water stress following planting or on the root-to-shoot ratio of the seedlings after one growing season.

Despite limited information on effects of the treatment, jellyrolling is being practiced by many foresters. The objective of the present study was to determine the effects of jellyrolling and acclimatization on first-year survival and height growth of ponderosa pine and Douglas-fir seedlings planted on a wide variety of sites in eastern Oregon and Washington. It is hoped this information will aid foresters in evaluating techniques to increase survival and growth of bare-root conifer planting stock.

[2/] Unpublished report, 1982, "Seedling Handling Technique Improves Growth of 3/0 Ponderosa Pine," by J.L. Dunbar, on file at U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208.

[3/] Research study 232/19, 1979, "Bare-Root Seedling Handling and Planting Practices," by D.L. Miller, Potlatch Corporation, Lewiston, ID 83501.

[4/] Personal communication, W.R. Terrill, P.O. Box 466, Tonasket, WA 98855.

Methods

1984 Tests

Field tests were conducted at eleven sites in Oregon and three in Washington in 1984, and at one site in Washington in 1983 (fig. 1). During 1984, nine tests were conducted with ponderosa pine, four with Douglas-fir, and one with lodgepole pine for a total of 11,200 seedlings. All tests were conducted with 2-year-old, bare-root, nursery-grown seedlings. All but one of the tests were conducted on clearcut harvested areas; the tests covered a wide range of site conditions (table 1). Elevations ranged from 1250 to 2020 m, and slopes from 0 to 55 percent. Several aspects were represented, but most units faced south or east. Average annual precipitation ranged from 15 to 177 cm, and mean annual temperature from 2.8 to 16.7 °C. Eleven of the units were harvested from 1980 to 1983, one unit was cut in 1972 and another in the 1930's, and one was an old burn. On most units, residue was broadcast burned or piled and burned. Soil depths ranged up to 208 cm, and water-holding capacity was considered good.

Figure 1.—Location of National Forest Ranger Districts in Washington and Oregon where control and treated ponderosa pine, Douglas-fir, and lodgepole pine seedlings were planted in spring 1984. The Chelan site was planted in May 1983.

Table 1—Planting site characteristics and environmental conditions at time of planting test sites, 1984

National Forest and Ranger District	Elevation	Slope	Aspect	Annual precipitation	Mean annual temperature	Date of harvest	Residue treatment, site preparation[1/]	Planting method	Soil depth	Conditions during planting: Air temperature	Relative humidity	Soil water tension	Soil temperature
	meters	percent		cm	°C				cm	°C	percent	bars	°C
Colville:													
Colville	1460	25-30	E	64	7.8	1983	P	Auger	30	10.5	47	—	5.5
Wenatchee:													
Naches	1280	25	NE	177	5.6	1983	BB	Hoe	30-90	20.7	42	0.20	7.8
Entiat	1250	20	S-SW	35	9.4	1982	BB	Hoe	180	11.6	82	.13	8.0
Malheur:													
Long Creek	1620	55	NW	63	5.2	1980	BB	Auger	41	12.5	54	.10	10.0
Deschutes:													
Bend	1370	0-3	E	49	7.7	1981	PB	Auger	60-90	6.6	50	—	10.0
Fort Rock	1420	0	Flat	38	7.6	1930's	*	Machine	90+	14.4	42	—	10.6
Sisters	1250	0-5	SE	76	12.8	1982	PB	Auger	5-208	6.1	93	.10	10.0
Winema:													
Chemult	1475	0-20	SW	63	8.9	1981	MPB	Shovel	50-150	12.8	35	.48	5.6
Chiloquin	1340	5-10	W	33	16.7	Old burn	D	Auger	50-100	12.2	77	.18	12.8
Klamath	1540	0-5	W	63	8.3	1981	MPB	Hoe	30	3.9	60	.00	4.4
Fremont:													
Lakeview	2020	10	N-NW	37	7.8	1981	BB	Hoe	63-122	10.0	72	.00	10.0
Silver Lake	1900	32	S	38	2.8	1980	PB	Auger	50-100	11.6	68	.10	8.7
Umpqua:													
Diamond Lake	1430	40	E-SE	152	7.8	1972	CS	Hoe	60-240	18.0	54	.10	13.3
Siskiyou:													
Illinois Valley	1280	25	SE	154	11.9	1982	BB	Hoe	Up to 91	11.1	41	.20	7.2

* = no residue treatment, Whitfield "V" blade used to make furrows 91 cm wide; – indicates no measurement made.
[1/] Treatments include pile (P), pile and burn (PB), broadcast burn (BB), chemical spray (CS), machine pile and burn (MPB), and disked (D).

After seedlings were obtained from the nursery, they were kept in cold storage at 1 to 2 °C for periods ranging from 2 to 21 weeks prior to the tests. Seedlings within a given test were graded to obtain uniform top size and root mass. For all tests, top height of ponderosa pine seedlings ranged from 16.3 to 22.7 cm, stem diameter from 5.4 to 6.3 mm, seedling fresh weight from 20.3 to 27.8 gm, and shoot-to-root ratio (ovendry weight) from 1.8 to 2.7. Comparable values for Douglas-fir were 18.9 to 34.7 cm, 4.4 to 6.5 mm, 13.0 to 27.3 gm, and 1.2 to 2.0. Seedlings were divided into four groups by treatment. Seedlings designated as controls (C) did not receive additional moistening. Roots of seedlings designated as dipped (D) were immersed for several seconds in a peat moss-water slurry at the planting site before being planted. Seedlings designated as jellyrolled (J) were root-pruned to 30.5 cm. Roots were then dipped in a thick vermiculite-water slurry and were wrapped in wet burlap in bundles of 25 seedlings each. Seedlings were jellyrolled 1 day before planting and were kept in cold storage at 1 to 2 °C. Seedlings designated as jellyrolled and acclimatized (J + A) were jellyrolled 1 day before planting and then were placed in a tent or shed at ambient temperature for about 24 hours. For the Entiat site (see fig. 1), seedlings were acclimatized in a growth chamber at 10 °C, 90 percent RH (relative humidity), and a light intensity during a 16-hour light period of about 3.5 W/m^2 (300 fc).

Seedlings were planted by USDA Forest Service crews from March to June 1984. During planting, crews were rotated systematically among treatments to reduce bias. At each test site, seedlings were planted in eight plots, each containing 100 seedlings, for a total of 800 seedlings. Each plot consisted of four rows of seedlings, each row of 25 seedlings representing one treatment, with rows randomized within plots. Most seedlings were planted with a tree planting hoe or auger. Air temperature during planting ranged from 3.9 to 20.7 °C, soil temperature (20.3 cm depth) from 5.5 to 13.3 °C, and relative humidity from 35 to 93 percent (table 1). Soil water tensions ranged from 0 to 0.48 bar, but most values were 0.20 bar or less. Estimated wind speeds ranged from 0 to 32 km/h, and cloud cover from clear to overcast. At the Entiat site, seedlings were planted during intermittent showers. After planting, heights of seedlings were measured. In autumn, survival was tallied and heights were remeasured.

1983 Test

In a separate test, 1,200 2-0 bare-root seedlings each of ponderosa pine and Douglas-fir were planted on three sites in the Chelan Ranger District (Wenatchee National Forest) in north-central Washington in May 1983 (fig. 1.) Elevation of the sites is 1300 m, average annual precipitation is 80 cm per year, and mean annual temperature is 6 °C; aspects were east, south, and west. Slope ranged from 20 to 70 percent. Burned by a severe forest fire in 1970, the area contained few trees, despite earlier attempts at reforestation.

Average top height for graded pines was 17.2 cm, stem diameter 5.8 mm, fresh weight 20.2 gm, and shoot-to-root ratio 2.9. Values for fir were 19.0 cm, 4.9 mm, 12.0 gm, and 1.3. Treatments were identical to those in the 1984 test except that the seedlings were acclimatized for 48 hours in a tent (temperature 8.5 to 20.0 °C; relative humidity 45 to 98 percent) near the planting site.

Four plots each of fir and pine were planted on each of the three sites, with treatments in rows as before. Seedlings were planted with a hoe-type tool. Temperature during planting ranged from 16.5 to 24.5 °C, and relative humidity from 24 to 37 percent; it was clear and sunny. Soil moisture tension ranged from 0.08 to 0.47 bar.

Seedling Moisture Stress

During planting at the Chelan site, moisture stress of 10 seedlings from each treatment was determined with a pressure chamber (Waring and Cleary 1967) to characterize moisture stresses of seedlings delivered to the planting site. Moisture stress was similarly determined for fir seedlings at the Entiat site in 1984.

The main benefit of jellyrolling is thought to be prevention of desiccation of seedlings during handling and while they are being carried in planting bags. To test this, control, dipped, and jellyrolled seedlings were placed in planting bags with the tops of the seedlings exposed; the bags were placed outdoors on a warm sunny day. Temperature ranged from 27.0 to 32.5 °C and relative humidity from 18 to 32 percent, which created a considerably higher evaporative demand than would normally be encountered during planting. The moisture stress experiment was a completely randomized design. Moisture stress of whole shoots was determined immediately prior to exposure to obtain initial stress values, and twice again during an exposure period of approximately 2½ hours. Twelve seedlings from each treatment were measured each time. Root systems of the pine seedlings appeared visibly drier than those of the fir seedlings and, indeed, initial moisture stresses for control and dipped pine seedlings were somewhat higher than those for the fir.

The planting experiments were designed as randomized complete block designs with each site used as a block. Douglas-fir and ponderosa pine were separate experiments. Differences among the four treatments in survival and height growth were determined by analysis of variance and Tukey's multiple comparison procedure with $p \leq 0.05$.

Results

1984 Tests

Survival of ponderosa pine for all sites and treatments during the 1984 test ranged from 39 to 98 percent; height growth ranged from 7 to 28 percent (table 2). Average values of survival for pine for the C, D, J, and J + A treatments were 82, 86, 85, and 87 percent, respectively, and for height growth 16, 18, 17 and 15 percent, respectively. Survival of jellyrolled and acclimatized seedlings (J + A) was significantly higher ($p \leq 0.05$) than the survival of control seedlings, but no other differences among treatments for survival or growth were significant.

Survival of Douglas-fir for all sites and treatments ranged from 55 to 87 percent; height growth ranged from 14 to 22 percent. Average values of survival for the C, D, J, and J + A treatments were 77, 72, 74, and 70 percent, respectively, and for height growth 18, 19, 17, and 18 percent, respectively, with no significant differences among treatments. In the one test with lodgepole pine, survival was 99 percent for all treatments, and height growth ranged from 28 to 34 percent. Variability in survival among treatments was somewhat less in ponderosa pine, 2 to 13 percent, compared to 5 to 16 percent in the fir. Variability in height growth among treatments, on the other hand, was less in the fir, 0 to 3 percent, as compared to 2 to 12 percent for ponderosa pine.

1983 Test

In the 1983 Chelan test, survival of pine on three sites ranged from 54 to 94 percent, and height growth from 29 to 45 percent. Average values of survival in pine for the C, D, J, and J + A treatments were 70, 74, 70, and 80 percent, respectively, and height growth 38, 41, 34, and 37 percent, respectively. The high average value of survival for the J + A treatment was the result of high survival of J + A seedlings on one of the three sites. Survival of fir seedlings ranged from 97 to 100 percent; height growth ranged from 20 to 26 percent. Average survival of fir for three sites was high for all treatments, 98 to 99 percent, and values for growth ranged from 21 to 23 percent.

Table 2—First-year survival and height growth of ponderosa pine, Douglas-fir, and lodgepole pine seedlings following root dipping and jellyrolling, 1984

National Forest and Ranger District	Species	Survival[1] C	Survival[1] D	Survival[1] J	Survival[1] J+A	Height Growth[1] [2] C	Height Growth[1] [2] D	Height Growth[1] [2] J	Height Growth[1] [2] J+A
		Percent							
Colville:									
Colville	PP	95	97	94	94	28	26	19	16
Wenatchee:									
Naches	PP	79	90	91	87	24	28	26	25
Malheur:									
Long Creek	PP	87	91	90	93	9	10	12	11
Deschutes:									
Bend	PP	80	87	93	88	9	17	19	15
Fort Rock	PP	90	88	92	92	17	19	18	15
Winema:									
Chemult	PP	94	96	95	95	24	21	22	22
Chiloquin	PP	75	80	74	83	16	20	19	15
Klamath	PP	42	44	39	50	7	9	7	7
Fremont:									
Lakeview	PP	95	97	98	98	13	14	12	12
Average[3]		82a	86ab	85ab	87b	16c	18c	17c	15c
Wenatchee:									
Entiat	DF	82	56	70	65	19	18	16	16
Deschutes:									
Sisters	DF	59	61	59	55	22	22	22	22
Umpqua:									
Diamond Lake	DF	82	86	80	76	15	18	16	16
Siskiyou:									
Illinois Valley	DF	86	86	87	82	15	16	14	17
Average[3]		77d	72d	74d	70d	18e	19e	17e	18e
Fremont:									
Silver Lake	LP	99	99	99	99	29	32	28	34

[1] Treatments were control (C), dipped (D), jellyrolled (J), and jellyrolled and acclimatized (J + A).
[2] Height growth equals the increase in height divided by the initial height, multiplied by 100.
[3] Treatment means followed by the same letter were not significantly different at the 0.05 level.

Seedling Moisture Stress

Moisture stresses in fir and pine seedlings for the Chelan test prior to planting were significantly higher ($p \leq 0.05$) in the J + A seedlings (5.0 to 9.5 bars) than moisture stresses in the C, D, or J seedlings (2.5 to 5.5 bars) (table 3). Within species, no other differences among treatments were significant. At the Entiat site, moisture stresses in fir seedlings were significantly higher ($p \leq 0.05$) in the C and J + A seedlings (3.2 to 4.4 bars) than stresses in D or J seedlings (1.7 to 2.4 bars). Other differences among treatments were not significant. In fir, J seedlings generally exhibited the lowest moisture stress, but values were not significantly lower. Values for pine are not directly comparable to those for fir because the tops of the pine seedlings were kept exposed during the period of measurement, whereas the fir was kept enclosed.

Initial moisture stresses (time zero) in fir seedlings in a planting bag ranged from 1.4 to 4.1 bars (fig. 2). Moisture stresses for all treatments increased with time, and at 147 minutes, stresses ranged from 7.3 bars for jellyrolled seedlings to 16.0 bars for control seedlings. At time zero, all means were significantly different ($p \leq 0.05$) except for C versus D, and D versus J. At 66 and 147 minutes, the mean value for C was significantly higher ($p \leq 0.05$) than for D, J, or J + A; the latter three treatments were not significantly different from each other. In the case of ponderosa pine, initial stresses ranged from 4.2 to 7.2 bars. Moisture stress increased with time and at 125 minutes, values ranged from 15.3 bars for jellyrolled seedlings to 22.7 bars for the controls. At time zero, moisture stresses in both C and D seedlings were significantly higher ($p \leq 0.05$) than were stresses in J seedlings. At 63 minutes, the mean value for C was significantly higher ($p \leq 0.05$) than that for D but not J; at 125 minutes, the value for C was significantly higher ($p \leq 0.05$) than that for both D and J.

Table 3—Moisture stresses in control, root-dipped, and jellyrolled Douglas-fir and ponderosa pine seedlings prior to planting, Chelan and Entiat Ranger Districts[1/]

Species	Chelan				Entiat			
	C	D	J	J+A	C	D	J	J+A
	bars							
Douglas-fir[2/]	3.5a	3.5a	2.5a	5.0b	3.2ab	2.4a	1.7a	4.4b
Ponderosa pine[3/]	4.3a	3.8a	5.5a	9.5b	—	—	—	—

— indicates no measurement made.
[1/] Treatments were controls (C), dipped (D), jellyrolled (J), and jellyrolled and acclimatized (J + A). Treatment means for a species followed by the same letter were not significantly different at the 0.05 level of probability.
[2/] Seedlings were kept in a closed box during measurements.
[3/] Seedlings were kept in an open box with seedling tops exposed.

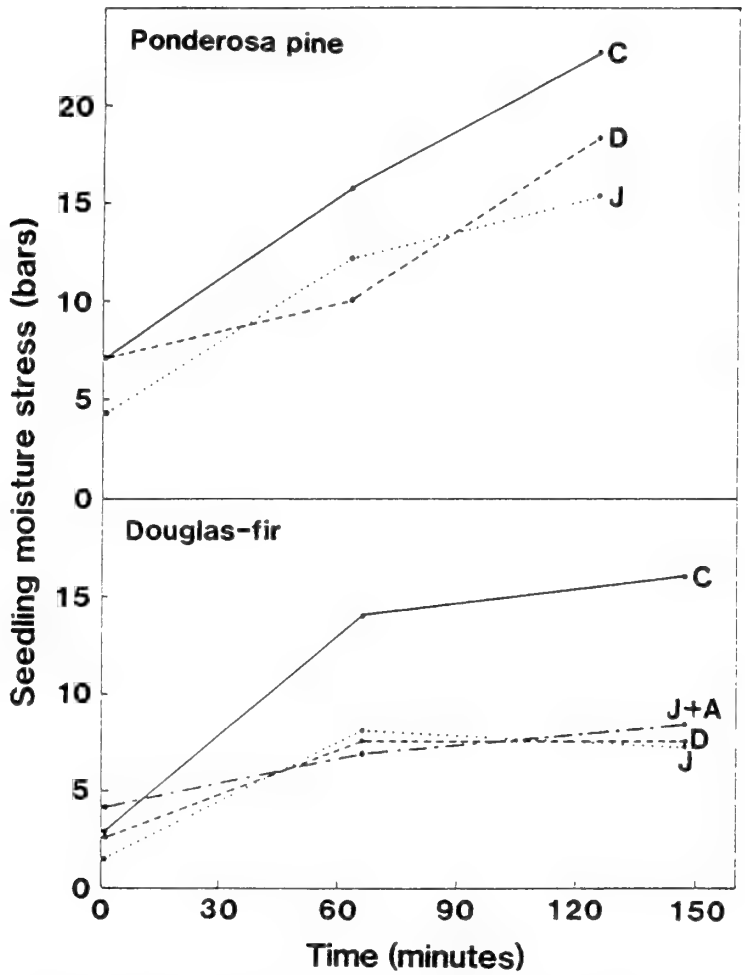

Figure 2.—Moisture stress in control (C), root-dipped (D), jellyrolled (J), and jellyrolled and acclimatized (J + A) ponderosa pine and Douglas-fir seedlings in a planting bag with the tops exposed on a warm sunny day.

Discussion

In the 1984 field tests, jellyrolling of seedlings did not increase survival significantly over survival of control or dipped seedlings. Although survival of pine seedlings that had been both jellyrolled and acclimatized was significantly higher than that of untreated seedlings, the increase in survival was only 5 percent, which may not be sufficient to justify the added cost of jellyrolling and acclimatization. More importantly, survival of jellyrolled and acclimatized seedlings was not significantly higher than that of slurry-dipped seedlings. There also was no effect from jellyrolling or acclimatization on seedling height growth. Survival results for Douglas-fir were just the opposite; that is, survival was lowest in the jellyrolled and acclimatized seedlings and was highest in the controls with no significant differences among treatments. In the Chelan test, the average value for survival of jellyrolled plus acclimatized pine seedlings was higher than that for the other treatments only because of higher survival on one of the three test sites. That, plus the very high and equal survival of the fir seedlings for all treatments, made the Chelan results inconclusive. Collectively, the results indicated that there were no significant beneficial effects of jellyrolling or acclimatization on survival or height growth of ponderosa pine and Douglas-fir seedlings compared to simply dipping seedlings prior to planting.

From a physiological standpoint, there is little to support jellyrolling. The small amount of water absorbed by jellyrolled seedlings would be transpired in a short time following outplanting. Maintenance of root tissue hydration undoubtedly is important for efficient water absorption, but it is doubtful whether properly stored seedlings with damp root systems would benefit much from additional moistening. Seedlings that have dried considerably during storage obviously should be remoistened, but that can be accomplished without jellyrolling. In the present study, moisture stresses of nontreated controls measured prior to planting ranged from 3.2 to 4.3 bars (table 3)—stress levels typical of moist, cold-stored seedlings and too low to affect performance.

There is little evidence that allowing cold-stored seedlings to warm up briefly prior to planting is beneficial. It should be noted, however, that there were no indications in the present tests, or in previously cited studies, that exposure of seedlings to moderate temperatures for 1 or 2 days prior to planting is detrimental to survival or growth. It is tempting to speculate that coniferous seedlings subjected to prolonged cold and dark storage may require gradual exposure to warmer temperatures and perhaps increased light to begin normal functioning—particularly stomatal control of water loss—and that the response varies with species. The positive effects of acclimatization with pine in the present study could be taken to support this; however, information in this area is very limited. McCracken (1978) did find that cold storage reduced the rate of recovery of CO_2 uptake in seedlings of *Pinus mugo* Turra and *Pinus radiata* D. Don., and speculates that adjustment to light may be necessary following prolonged cold and dark storage. Recently Grossnickle and Blake (1985), working with seedlings of jack pine and white spruce (*Picea glauca* (Moench) Voss), found that stomatal conductance increased and seedling resistance to water flow decreased during the 18-20 days following removal of the seedlings from cold storage. No changes were observed after only 2 days, the amount of time often used to acclimatize jellyrolled seedlings.

In the present study, exposure of the tops of the seedlings during acclimatization did result in slightly elevated moisture stresses; the stress levels of 4.4 to 5.0 bars in fir seedlings (table 3) are, however, not excessive for planting stock (Cleary and others 1978). The higher value of 9.5 bars in pine undoubtedly was the result of shoot exposure in those seedlings during measurements on the planting site. Apparently, survival of those seedlings was not adversely affected by this level of stress. Perhaps a greater concern with acclimatization is that it requires more careful scheduling of planting operations once acclimatization is started, and field acclimatization at higher elevations risks freezing seedlings. Another consideration is cost. Costs of jellyrolling vary somewhat, but once the procedure is operational, costs are reported to average around $10 per thousand seedlings.

Results in the present test may have been influenced by several factors. The cool and moist conditions that occurred during the 1984 planting season may not have provided sufficiently stressful conditions for the test. The 1983 Chelan test, however, was conducted under ideal conditions. Another factor is the potential for seedlings drying out while in planters' bags. Planters may carry seedlings for several hours, which would provide greater opportunity for seedling desiccation than occurred during test plantings when seedlings were planted in groups of 25. Measurement of seedling moisture stresses in a planting bag with the seedling tops exposed showed that unmoistened seedlings developed considerably higher stresses than dipped or jellyrolled seedlings, which generally exhibited lower and generally similar stresses.

In conclusion, there appears to be no advantage, in terms of survival, height growth, or stress reduction, from jellyrolling or acclimatizing bare-root conifer seedlings as compared to simply root-dipping them in peat moss-water or vermiculite-water slurries at the planting site.

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English Equivalents

1 meter (m) = 39.37 inches or 3.28 feet
1 centimeter (cm) = 0.3937 inch
1 millimeter (mm) = 0.03937 inch
1 gram (gm) = 0.03527 ounce or 0.0022 pound
degrees Celsius (°C) = (degrees Fahrenheit–32)/1.8
kilometers per hour (km/h) = 0.6214 miles per hour
1 bar = 14.504 pounds per square inch

Literature Cited

Belli, K.L.; Dickmann, D.I. Effect of preplant spraying or soaking on growth and water relations of jack pine (*Pinus banksiana* Lamb.) seedlings. Tree Planters' Notes. 36: 24-27; **1985.**

Chavasse, C.G.R. Planting stock quality: a review of factors affecting performance. New Zealand Journal of Forestry. 25: 144-171; **1980.**

Cleary, B.D.; DeYoe, D.R. Seedling care and handling. Ext. Circ. 1095. Corvallis, OR: Oregon State University Extension Service; **1982:** [pages unknown].

Cleary, B.D.; Greaves, R.D.; Hermann, R.K. Regenerating Oregon's forests. A guide for the regeneration forester. Corvallis, OR: Oregon State University Extension Service; **1978.** 286 p.

Dahlgreen, A.K. Care of forest tree seedlings from nursery to planting hole. In: Baumgartner, D.M.; Boyd, R.J., eds. Tree planting in the Northwest. Pullman, WA: Washington State University Cooperative Extension Service; **1976:** 205-238.

Dierauf, T.A.; Marler, R.L. Clay dipped vs. bare root seedling survival. Tree Planters' Notes. 20: 5-8; **1969.**

Feret, P.P.; Kreh, R.E.; Mulligan, C. Effects of air drying on survival, height, and root growth potential of loblolly pine seedlings. Southern Journal of Applied Forestry. 9: 125-128; **1985.**

Grossnickle, S.C.; Blake, T.J. Acclimation of cold-stored jack pine and white spruce seedlings: effect of soil temperature on water relation patterns. Canadian Journal of Forest Research. 15: 544-550; **1985.**

Hermann, R.K. The effect of short-term exposure of roots on survival of 2-0 Douglas-fir stock. Tree Planters' Notes. 52: 28-30; **1962.**

Hermann, R.K. Seasonal variation in sensitivity of Douglas-fir seedlings to exposure of roots. Forest Science. 13: 140-149; **1967.**

Lotan, J.E.; Perry, D.A. Ecology and regeneration of lodgepole pine. Agric. Handb. 606. Washington, DC: U.S. Department of Agriculture; **1983.** 51 p.

McCracken, I.J. Carbon dioxide uptake of pine seedlings after cool storage. Forest Science. 24: 17-25; **1978.**

Mullin, R.E. Some effects of root dipping, root exposure and extended planting dates with white spruce. Forestry Chronicle. 47: 90-93; **1971.**

Owston, P.W.; Stein, W.I. Coating materials protect Douglas-fir and noble fir seedlings against drying conditions. Tree Planters' Notes. 23: 21-23; **1972.**

Waring, R.H.; Cleary, B.D. Plant moisture stress: evaluation by pressure bomb. Science. 155: 1248-1254; **1967.**

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