Effects of Storage, Handling and Transportation on Eastern White Pine 1st-Year Survival and Height

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Abstract

Eighteen treatments were tested in a study replicated three times on each of three sites using 2-0 eastern white pine seedlings lifted at the Augusta nursery in February through April of 2005. This report summarizes the results of previous research and the first-year data from this study in Augusta, Floyd and Grayson counties. The data were averaged across study sites because statistical analysis showed no treatment x site interaction.

Seedlings exposed to the elements during transportation or planting and those stored for 8 weeks initiated height growth significantly later than the others. Survival ranged from 46 to 91 percent and was reduced by cold storage over 4 weeks when combined with prolonged exposure to sun and air during planting, and exposure during transportation. Seedling height averaged between 0.4 and 0.9 feet after one year, and was lower with increased cold storage, shipping exposure, and planting exposure. Overall seedling performance was quite poor when two of these stressors were applied in combination. For example, only 17 percent of seedlings stored for eight weeks and then exposed to sun and air for 60 minutes before planting were acceptable. There was no evidence that either exposure up to two hours during grading or application of gel root dip had any substantial effects on the seedlings' performance regardless of other factors.

Based on these results and previous research, the best practices to ensure eastern white pine survival include: avoid all exposure to sun and wind during planting; protect seedlings from drying and heating during transportation; plant earlier instead of later (February through April, depending on weather)**;** control competing vegetation and sod in old-field plantings; minimize

time in cold storage; plant the largest seedlings available and practical (to accelerate height growth)**;** and avoid root pruning at time of planting.

Introduction

Eastern white pine (*Pinus strobus* L.) is the most common and commercially important tree species planted in the mountains of southwest Virginia. In recent years, survival of eastern white pine (EWP) plantings has been variable and in some cases unacceptable. There are numerous possible reasons for seedling mortality, which may act alone or in combination to create plantation failures. Fortunately, a great deal of research has already been reported on this subject; the Virginia Department of Forestry research team has investigated a number of questions regarding how handling and planting practices may affect EWP survival and growth.

A review of data from EWP plots installed in Virginia over the last 40 years suggests that low and / or variable first-year survival of EWP is not a new phenomenon. In a three-year survey of 150-200 plots per year between 1959 and 1962, survival of spring-planted EWP averaged between 65 and 88 percent on old fields and between 74 and 86 percent on cutover sites (Marler 1963). In 1965-1966, survival ranged from 4 to 86 percent with an average of 45 percent, depending on whether the roots were clay dipped and on how long the seedlings were exposed during planting (Dierauf and Marler 1967). A series of root pruning test plots installed from 1980 to 1984 found survival ranging from 15 to 97 percent (Dierauf and Hannah 1989). Depending on lifting date and storage time, between 1982 and 1985 survival ranged between 23 and 95 percent (Dierauf 1989). In a series of five nursery undercutting studies, survival ranged from 51 to 93 percent in 1988, 44 to 86 percent in 1989, 49 to 72 percent in 1990, and 57 to 88 percent in 1991 (Dierauf et al 1995). And in a separate storage study in 1990-1991, survival varied between 52 and 92 percent (Dierauf and Chandler 1995). There is a history of variable survival of EWP in Virginia.

The key question is – what causes the variation? Obviously, some factors beyond our control – like drought, temperature extremes, and insect or disease outbreaks - can and do cause mortality. Controllable variables that have been investigated include:

1. Increasing **exposure while planting** (i.e. carrying the seedlings in hand, exposed to sun, heat, and / or wind) - even for a few minutes - causes increased mortality (Dierauf and Marler 1967).

2. **Root pruning at planting** reduces survival, and increasing the severity of pruning multiplies the loss (Dierauf and Hannah 1989).

3. Increasing **time in cold storage** decreases survival (Dierauf 1989).

4. **Later planting dates** decrease survival. Depending on location and climate, this effect begins to be expressed anywhere between May and late June (Rexrode and Carvell 1981).

5. **Competing vegetation**, especially sod in old-field settings, can cause significant first-year mortality (Tigner 2004).

6. **Rough handling** has been shown to decrease root growth potential and growth initiation in white pine (Yuyitung, et al). Dropping seedlings from a height of just 1-2 meters produces this effect, which could, in turn, reduce survival (although that has yet to be tested).

7. **Clay dipping** to protect roots has not been shown to consistently affect survival; it had a positive effect in one year and negative in the next (Dierauf and Marler 1967).

8. **Lifting and planting dates** in November or December or lifting in late November or December with protected (i.e. boxed) storage until March planting appear to have little effect on survival and might be an option to expand the lifting window (Dierauf 1989).

9. Increasing **seedling size** (over the range between $^{2}/_{32}$ and $^{5}/_{32}$ inch root collar diameter) does not affect survival but does significantly accelerate early height growth (Ward et al 2000, Dierauf and Chandler 1995, Bean and Allen).

10. **Planting depth** does not usually affect survival (Mullin 1967, Carvell and Kulow 1964), although Tigner (2004 – see below) did find that extremely shallow planting caused mortality.

11. **Root pruning in nursery** beds improves survival and height growth (Dierauf et al 1995).

There are also a number of variables which have not been examined in EWP plantings, including:

1. Root protection using gel dip instead of clay dip;
2. Packaging method (traditional open-ended bundles vs kraft bags);
3. Transport effects (refrigerated vs. open trucks);
4. Grading exposure effects; and
5. Rough handling effects (i.e. dropping / throwing seedling bundles or bags).

Tigner (2004) summarized observations from a 2003 test of lifting, handling, storage and processing factors. In March 2003, a 12-treatment study using one 20-tree row plot per treatment and replicated six times – once each in Augusta, Carroll, Floyd, Franklin, Rockingham and Washington counties – was installed. Observations from nursery operations indicated that staffing was inadequate to keep seedlings moving quickly from field to cold storage or from cold storage through the grading and packing process. In addition, field units did not always take appropriate measures to prevent desiccation of seedling bundles in transit from the nursery to local storage. The treatments tested in the study compared seedling sizes, grading exposures, planting depths, dipping treatments, lifting exposures, storage times, and root pruning intensities. Survival after one year ranged from 32 percent to 88 percent. Trees handled with the greatest care survived best. Hand lifting was better than operational lifting. Storage exceeding three months greatly reduced survival. Shallow planting greatly reduced survival. Extremely small seedlings survived poorly. Overall, the test reinforced the concept that numerous factors can contribute to EWP mortality, and most are avoidable.

Methods

On February 17, 2005, 2-0 eastern white pine seedlings for this study were randomly selected from the Virginia Department of Forestry's Augusta Nursery operational lifting. They were transferred immediately to the grading building where they were graded as rapidly as possible and then either transferred directly to the storage cooler or left exposed on the grading table for 30, 60, or 240 minutes after grading before being placed in the cooler.

On March 18-21, 2005 and again on April 18-19, 2005, additional seedlings were lifted and – along with those stored since February 17 - transported to the planting locations. On May 17-18, 2005, recently-lifted (within 2 weeks) seedlings from the operational program were retrieved from coolers at Augusta, Salem, and Galax.

Test plots were installed at three locations: in Augusta County (at the Augusta Forestry Center); in Floyd County (near Burkes Fork Creek); and in Grayson County (on the Matthews State Forest). All three locations were on flat to gently sloping old field sites with an established grass / sod cover. Seedlings for each of the 18 treatments (Table 1) were planted in 15-tree rows replicated three times in a randomized complete block experimental design at each location. Planting dates were March 18-21, April 18-19, and May 17-18, 2005.

Table 1. Treatments compared in the 2005 eastern white pine survival effects tests in Augusta, Floyd, and Grayson counties, VA.

Treatment #	Date Lifted	Date Planted	Grading Exposure (min.)	Planting Exposure (min.)	Other
1	March	March	0	0	
2	March	March	0	0	Jeep-top
3	February	March	0	0	
4	February	March	30	0	
5	February	March	60	0	
6	February	March	120	0	
7	February	March	0	30	
8	February	March	0	60	
9	February	March	0	120	
10	April	April	0	0	
11	April	April	0	0	Gel Dip
12	February	April	0	0	
13	February	April	0	30	
14	February	April	0	60	
15	February	April	120	0	
16	May	May	0	0	Augusta source
17	May	May	0	0	Salem source
18	May	May	0	0	Galax source

	Planted March, 2005 (treatments 1-9)
	Planted April, 2005 (treatments 10-15)
	Planted May, 2005 (treatments 16-18)

The seedlings were assessed in mid-May (March and April plantings) and mid-June (May plantings) for early survival and growth initiation, and year-end height and survival were

recorded in September. Data were analyzed using 3-way analysis of variance with location, rep, and treatment as independent variables. Percent of seedlings initiating growth by May or June and year-end height, percent survival, and percent of seedlings growing well (defined as alive and over 6 inches in height) were analyzed as dependent variables. All percentage data were arcsin square root transformed before analysis. Whenever the ANOVA indicated significant effects, the Holm-Sidak technique was used to separate the means.

Results

There were significant effects of location on all parameters measured at all measurement dates. In each case, the results ranked in the same order: Augusta > Floyd > Matthews. There were definite differences among the three locations in site characteristics (soils, aspects) and competition levels. Figures 1 through 3 show how differently the vegetation developed, for example. In every case, sod control (either chemical or mechanical) would have likely enhanced survival (Tigner 2004, Dierauf and Chandler 1995).

Figure 1. July 2005 photo of the Augusta County study site.

Figure 2. June 2005 photo of the Floyd County study site.

Figure 3. July 2005 photo of the Grayson County study site.

There were no statistically-significant site x treatment interactions, so for all of the remaining analyses the data were lumped across locations.

Initiation of Growth

By mid-June, statistically significant treatment effects were already apparent (Tables 2 and 3). The early evidence suggested that seedling growth initiation was delayed by stress from 1) transportation exposure (Jeep-top), 2) exposure during planting, and 3) extended cold storage (8 weeks). In addition, the May plantings showed a difference due to seedling storage location, which implies an undetermined difference in either transportation or storage conditions.

Survival

Seedling survival data at the end of the first growing season (Table 4) appeared consistent with the earlier observations on height growth initiation. Survival was lowest for treatments imparting stress due to either 1) cold storage for 8 weeks before planting, 2) exposure during planting, or 3) exposure during transport. The May planting date showed differences among storage locations, again indicating an effect of either transport or storage. Further, all of the May plantings suffered elevated mortality, confirming that late planting is another practice to be avoided.

Table 2: Percentage of eastern white pine seedlings planted in March and April with evidence of growth (bud elongation or needled development) in mid-May. Overall means are ranked in descending order. Those followed by different letters are significantly different at the 0.05 level.

#	Treatment	Augusta	Floyd	Grayson	Average
3	4 wk. storage	69	60	45	58 a
4	4 wk. storage, 30 min. grading	56	66	49	57 ab
10	Zero storage, zero exposure	69	49	51	56 ab
6	4 wk. storage, 120 min. grading	60	47	58	55 ab
1	Zero storage, zero exposure	58	47	40	48 ab
7	4 wk. storage, 30 min. planting	38	62	31	44 ab
5	4 wk. storage, 60 min. grading	44	51	24	40 ab
11	Zero storage, zero exposure, gel dip	36	42	42	40 ab
8	4 wk. storage, 60 min. planting	55	51	11	39 b
2	Zero storage, exposed transport	42	47	20	36 b
9	4 wk. storage, 120 min. planting	0	42	0	14 c
12	8 wk. storage	5	2	11	6 c
14	8 wk. storage, 60 min. planting	5	0	0	1.7 c
13	8 wk. storage, 30 min. planting	0	0	0	0 c
15	8 wk. storage, 120 min. grading	0	0	0	0 c

	Planted March, 2005 (treatments 1-9)
	Planted April, 2005 (treatments 10-15)

Table 3: Percentage of eastern white pine seedlings initiating height growth by mid-June. Overall means are ranked in descending order. Those followed by different letters are significantly different at the 0.05 level.

#	Treatment	Augusta	Floyd	Grayson	Average
1	Zero storage, zero exposure	93	71	87	84 a
16	2 wk. storage at Augusta	60	62	75	66 b
17	Transport to and 2 wk. storage at Salem	71	60	62	64 b
18	Transport to and 2 wk. storage at Galax	55	36	53	48 c

	Planted March, 2005 (treatment 1)
	Planted May, 2005 (treatments 16-18)

Height

After one growing season, the tallest seedlings were those with zero storage and zero exposure (Table 5); across locations, they averaged .9 feet in height. The data suggest that all other treatments caused a loss of height growth. The seedlings that experienced the combination of the longest storage time (8 weeks) and exposure during planting were the shortest, and were at a level that would make them unlikely to successfully survive and compete in the heavy grass competition on these sites in the future.

Table 4: Percent of planted eastern white pine seedlings surviving at the end of the 2005 growing season. Overall means are ranked in descending order. Those followed by different letters are significantly different at the 0.05 level.

#	Treatment	Augusta	Floyd	Grayson	Average
3	4 wk. storage	1.00	0.76	0.96	0.91 a
6	4 wk. storage, 120 min. grading	1.00	0.82	0.89	0.90 ab
4	4 wk. storage, 30 min. grading	0.98	0.76	0.93	0.89 abc
1	Zero storage, zero exposure	0.95	0.85	0.82	0.87 abcd
5	4 wk. storage, 60 min. grading	1.00	0.69	0.87	0.85 abcde
12	8 wk. storage	1.00	0.73	0.80	0.84 abcde
10	Zero storage, zero exposure	0.98	0.58	0.91	0.82 abcde
11	Zero storage, zero exposure, gel dip	0.86	0.65	0.91	0.81 bcdefg
17	Transport to storage at Salem	0.82	0.69	0.89	0.80 cdefgh
7	4 wk. storage, 30 min. planting	1.00	0.73	0.64	0.79 cdefgh
8	4 wk. storage, 60 min. planting	0.93	0.73	0.67	0.78 cdefgh
16	Transport to storage at Augusta	0.76	0.64	0.87	0.76 defgh
2	Zero storage, exposed transport	0.93	0.67	0.54	0.71 efghi
13	8 wk. storage, 30 min. planting	0.84	0.60	0.62	0.69 fghi
15	8 wk. storage, 120 min. grading	0.76	0.54	0.73	0.68 ghi
18	Transport to storage at Galax	0.71	0.42	0.76	0.63 hi
9	4 wk. storage, 120 min. planting	0.69	0.67	0.40	0.59 ij
14	8 wk. storage, 60 min. planting	0.55	0.49	0.33	0.46 j

	Planted March, 2005 (treatments 1-9)
	Planted April, 2005 (treatments 10-15)
	Planted May, 2005 (treatments 16-18)

Figure 4. Survival of seedlings planted on March 21, 2005.

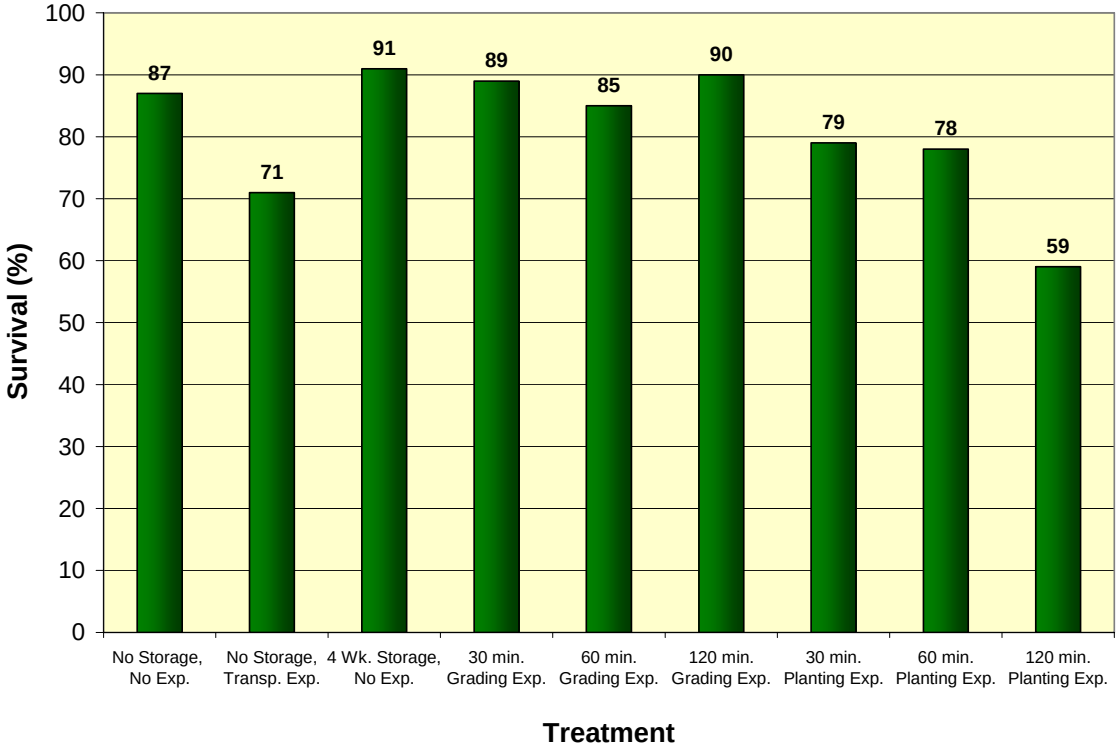

Figure 5. Survival of seedlings planted on April 18, 2005.

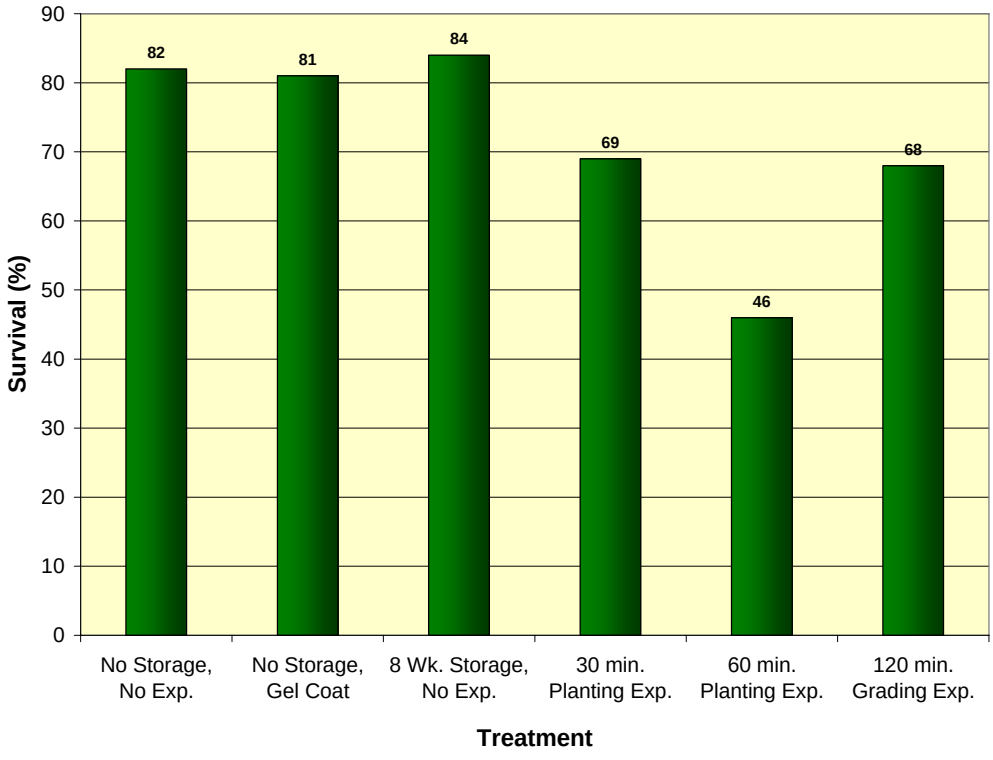

Table 5: Height of planted eastern white pine seedlings at the end of the 2005 growing season. Overall means are ranked in descending order. Those followed by different letters are significantly different at the 0.05 level.

#	Treatment	Augusta	Floyd	Grayson	Average
1	Zero storage, zero exposure	0.91	0.80	0.93	0.88 a
2	Zero storage, exposed transport	0.76	0.72	0.79	0.76 bc
6	4 wk. storage, 120 min. grading	0.85	0.63	0.81	0.76 bc
4	4 wk. storage, 30 min. grading	0.83	0.69	0.67	0.73 bcd
11	Zero storage, zero exposure, gel dip	0.84	0.60	0.68	0.71 bcde
5	4 wk. storage, 60 min. grading	0.73	0.68	0.67	0.69 bcde
10	Zero storage, zero exposure	0.74	0.65	0.66	0.68 bcde
3	4 wk. storage	0.88	0.48	0.64	0.67 bcdef
12	8 wk. storage	0.83	0.53	0.66	0.67 bcdef
7	4 wk. storage, 30 min. planting	0.74	0.58	0.62	0.65 cdef
17	Transport to and 2 wk. storage at Salem	0.77	0.48	0.68	0.64 def
16	2 wk storage at Augusta	0.65	0.46	0.79	0.63 def
8	4 wk. storage, 60 min. planting	0.73	0.59	0.53	0.62 efg
9	4 wk. storage, 120 min. planting	0.68	0.53	0.48	0.56 fg
18	Transport to and 2 wk. storage at Galax	0.62	0.42	0.62	0.55 fg
15	8 wk. storage, 120 min. grading	0.57	0.45	0.59	0.54 g
13	8 wk. storage, 30 min. planting	0.66	0.52	0.40	0.53 g
14	8 wk. storage, 60 min. planting	0.42	0.48	0.39	0.43 h

	Planted March, 2005 (treatments 1-9)
	Planted April, 2005 (treatments 10-15)
	Planted May, 2005 (treatments 16-18)

Seedling Performance

Because first-year height growth is very important in particular for seedlings trying to compete on sites with heavy grass or sod competition, we also divided the seedlings into “acceptable” and “unacceptable” categories depending on year-end height. Following the advice of Tigner (2004), we defined seedlings less than 6 inches (0.5 feet) in height as being unlikely to survive in heavy grass competition typical of the study sites. These results (Table 6) reinforce what we have already surmised: grading exposure is not a significant factor, but exposure to open sunlight and drying conditions during planting, extended time in cold storage (8 weeks) before planting, transportation exposure, and planting date have negative effects that are greatly magnified when those stressors are combined. Figure 6 shows how seedling performance trends lower for the April planting date (even for unstored seedlings) and how performance declines with planting exposure even more rapidly with 8 weeks storage than with 4. For the very worst treatment (8 weeks in storage plus 60 minutes of exposure prior to planting), only 17 percent of the planted seedlings were acceptable. Figure 7 shows an example of acceptable and unacceptable seedling appearance at the end of 2005.

Table 6: Percent of planted eastern white pine seedlings alive and showing acceptable height (defined as height greater than 0.5 feet) at the end of the 2005 growing season. Overall means are ranked in descending order. Those followed by different letters are significantly different at the 0.05 level.

#	Treatment	Augusta	Floyd	Grayson	Average
1	Zero storage, zero exposure	0.89	0.73	0.82	0.81 a
6	4 wk. storage, 120 min. grading	0.93	0.71	0.78	0.81 a
4	4 wk. storage, 30 min. grading	0.87	0.64	0.82	0.78 ab
5	4 wk. storage, 60 min. grading	0.93	0.60	0.76	0.76 ab
10	Zero storage, zero exposure	0.89	0.53	0.78	0.73 ab
3	4 wk. storage	0.89	0.44	0.80	0.71 ab
11	Zero storage, zero exposure, gel dip	0.80	0.53	0.71	0.68 ab
12	8 wk. storage	0.93	0.42	0.69	0.68 ab
2	Zero storage, exposed transport	0.87	0.60	0.49	0.65 ab
7	4 wk. storage, 30 min. planting	0.82	0.49	0.56	0.62 bc
17	Transport to and 2 wk. storage at Salem	0.76	0.36	0.76	0.62 bc
16	2 wk. storage at Augusta	0.64	0.31	0.82	0.59 cd
8	4 wk. storage, 60 min. planting	0.80	0.51	0.42	0.58 cd
15	8 wk. storage, 120 min. grading	0.58	0.24	0.53	0.45 de
18	Transport to and 2 wk storage at Galax	0.58	0.16	0.60	0.44 e
13	8 wk. storage, 30 min. planting	0.64	0.38	0.22	0.41 e
9	4 wk. storage, 120 min. planting	0.53	0.47	0.20	0.40 e
14	8 wk. storage, 60 min. planting	0.22	0.20	0.09	0.17 f

	Planted March, 2005 (treatments 1-9)
	Planted April, 2005 (treatments 10-15)
	Planted May, 2005 (treatments 16-18)

Figure 6. Effects of storage time and planting exposure on first-year eastern white pine seedling survival and height growth performance.

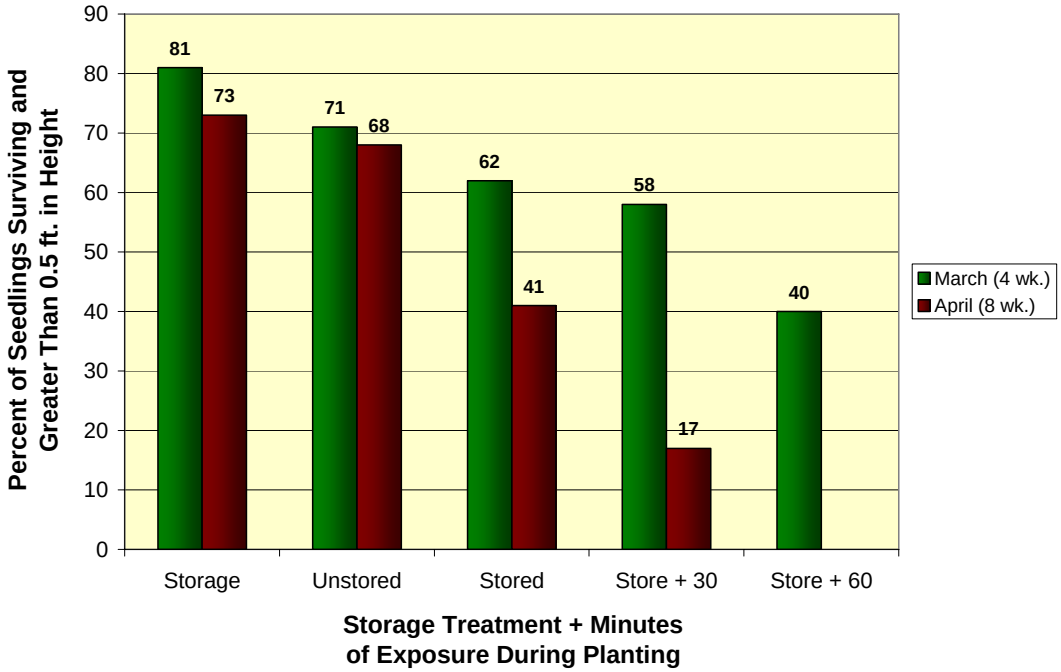

Figure 7. Differences in eastern white pine seedling performance.

Recommendations

1. **Avoid exposure during planting**. In this study and others before it, any exposure to sun and wind during planting causes mortality.

2. **Control competing vegetation** in old-field plantings. Use either herbicides or mechanical means such as scalping to remove dense sod cover.

3. **Plant earlier instead of later.** In this test, indications were that delayed planting led to reduced survival and growth. February through early April are preferred planting dates.

4. **Minimize time in cold storage**. In this test, anything greater than 4 weeks between lifting and planting resulted in reduced survival.

5. **Avoid seedling exposure to drying and heating during transportation**. The results of this test suggest that differences in shipping and/or storage can reduce survival.

6. **Plant the largest seedlings available and practical.** While this does not consistently improve survival, it does accelerate early growth which is important especially in old-field competition.

7. **Avoid root pruning** at time of planting.

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