OVERWINTER COLD STORAGE OF HARDWOOD NURSERY STOCK: EFFECTS ON OUTPLANTING PERFORMANCE

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INTRODUCTION

The ideal spring planting season for hardwoods in southwestern Ontario extends from the middle of April to the middle of May (von Althen 1979). Before the middle of April the soil temperature is near freezing and many planting sites are too wet for efficient planting. After the middle of May high temperatures and the danger of severe drought make planting inadvisable. Further, most hardwood nurseries in Ontario are located a considerable distance south of the majority of hardwood planting sites. Seedlings and transplants lifted in these nurseries after the middle of May may have flushed and may have undergone a major burst of root activity which makes it unlikely that they will produce the root extensions necessary to support adequate shoot growth during the first season (Webb and Dumbroff 1978).

Recent experiments have shown that overwinter cold storage of planting stock can assure high establishment success by maintaining high root regeneration capacity and overall seedling growth potential (Webb 1976, 1977). Overwinter cold storage can also extend the spring planting season without loss of survival or growth (von Althen and Webb 1978).

To determine suitable cold storage regimes and packaging methods for six commonly planted hardwood species in Ontario an experiment was initiated in the autumn of 1977. The results on the effects of cold storage and packaging methods on root regeneration and physiological quality have been published (Webb and von Althen 1980). This report presents the 3-year results on the effects of overwinter cold storage and packaging methods on outplanting performance.

METHOD

At the end of November 1977, 2+0 white ash *(Fraxinus americana* L.), silver maple *(Acer saccharinum* L.), red oak *(Quercus rubra* L.) and basswood *(Tilia americana L.)*, 1+0 black walnut *(Juglans nigra* L.) and 3+0 and 2+2 sugar maple *(Acer saccharum* Marsh.) were lifted at the Ontario Ministry of Natural Resources tree nursery at St. Williams, Ontario and transported directly to Sault Ste. Marie, Ontario. At time of lifting all stock was leafless and dormant. All species and age classes were graded for size and randomly allocated to different storage temperature and packaging treatments. Temperature treatments consisted of -10, -5, 0.5, 5, and 10°C ± 0.5°C. Relative humidities ranged from 70 to 85%.

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Within each temperature treatment, seedlings were subjected to the following three packaging treatments: 1) seedling roots were surrounded with moist peat and enclosed in Kraft bags with polyethylene liners sealed around the stem just above the root collar; 2) seedlings were totally enclosed in sealed Kraft bags with polyethylene liners with moist peat surrounding the roots; and 3) seedlings were totally enclosed in sealed Kraft bags with polyethylene liners without peat. In mid-April 1978 all trees were removed from storage. During the same period nursery stock of each species was spring-lifted from the same nursery beds as the cold-stored stock and a sample was transported to Sault Ste. Marie. Twelve trees per species and age class from each of the storage treatments and the spring-lifted controls were planted in plastic pots and placed in a greenhouse in Sault Ste. Marie under extended photoperiods of 16 hr and temperatures of approximately 18°C (night) and 28°C (day). After 30 days the trees were removed from the pots, the roots were washed, and the number of new, white first- and second-order lateral roots produced was recorded to determine root growth capacity.

All other trees were planted within 3 days following removal from cold storage or lifting from the nursery beds in southwestern Ontario. White ash, silver maple, red oak and sugar maple were planted in a farm field near Shipka, Huron County, Ontario. The soil was imperfectly drained sandy loam over clay till at a depth of 40 to 60 cm. The pH of the plow layer was 7.5 and the organic matter content was 3.6%. The Ontario Soil Survey (Hoffman et al. 1952) classifies the soil as Barrien sandy loam. Basswood and black walnut were planted in a former field near Hornby, Halton County, Ontario. The soil was imperfectly drained clay loam over clay till at a depth of 45 to 60 cm. The pH of the plow layer was 6.8 and the organic matter content was 2.8%. The Ontario Soil Survey (Gillespie et al. 1971) classifies the soil as Chinguacousy clay loam.

Both fields had been plowed and disked in the summer of 1977. All trees were machine planted at a spacing of 3 m between rows and 1.5 m within rows.

Weed control in each of the first three years after planting consisted of rototilling between the rows and spraying the unwanted vegetation within rows with 2 kg/ha of glyphosate.

All species and age classes were planted in randomized block arrangements with 10 to 14 trees in each of 16 treatments (five storage temperatures x three packaging methods plus a spring-lifted control). Survival and height were recorded at the end of each of the first three growing seasons and all data were subjected to analyses of variances. The significance of treatment means (P 0.05) was identified by Tukey's procedure. Non-measurement data were subjected to Chi-square tests of significance.

RESULTS AND DISCUSSION

Root growth

Overwinter storage temperature significantly affected root growth capacity of all species (Tables 1-7), whereas method of packaging had no significant effect on root growth. Root growth after 30 days in greenhouse conditions was significantly lower for all species, except sugar maple, stored at below-freezing temperatures than for trees stored at above-freezing temperatures or fresh planted. Storage at +10°C resulted in low root growth capacity of sugar maple seedlings and transplants because larger numbers of new roots were produced in storage than following transfer to greenhouse conditions. With the exception of black walnut no significant differences in the number of new roots produced were observed between seedlings stored at 5 and 0.5°C and the spring-lifted controls. In contrast, black walnut produced significantly higher numbers of new roots at 5 and 10°C than in the controls (Table 5). Sugar maple transplants produced significantly higher numbers of new roots in the spring-lifted control than in any other treatment (Table 7).

Survival

Overwinter storage temperatures significantly affected survival of all species and age classes (Tables 1-7) whereas packaging method had no effect on survival. First year survival was 94% or better for all species and age classes stored at above-freezing temperatures and in the spring-lifted controls. Storage at -10°C was detrimental to the survival of red oak, basswood and black walnut seedlings. It also significantly reduced survival of white ash, silver maple and sugar maple seedlings and sugar maple transplants. Storage at -5°C significantly reduced survival of white ash, red oak, and basswood and resulted in 100% mortality of black walnut.

Mortality in years two and three was relatively minor for white ash, silver maple, red oak and sugar maple planted in the sandy loam soil. However, many black walnut stored at 0.5°C died in year two and many basswood stored at 0.5°C died in year three. This mortality cannot be explained adequately because root growth capacity appeared relatively high. It is possible, however, that the imperfect drainage of the clay loam soil was responsible for much of this mortality because the soil was extremely wet during extended periods of high precipitation in the summers of 1978 and 1979.

Height growth

Storage temperature significantly affected height growth of all species except black walnut (Fig. 1). Overwinter storage at -10°C caused stem dieback of white ash and silver maple seedlings and sugar maple transplants. Storage at -5°C caused stem dieback of red oak seedlings and sugar maple transplants.

First year height growth of white ash seedlings was significantly lower following storage at -5 and -10°C than at all other temperatures (Table 1). However, temperature of storage did not significantly affect second or third year height growth.

First and second year height growth of silver maple seedlings stored at -10°C was significantly lower than that of the fresh planted seedlings (Table 2), whereas third year height growth was not significantly affected by storage temperature.

Storage temperature had no effect on the first or second year height growth of

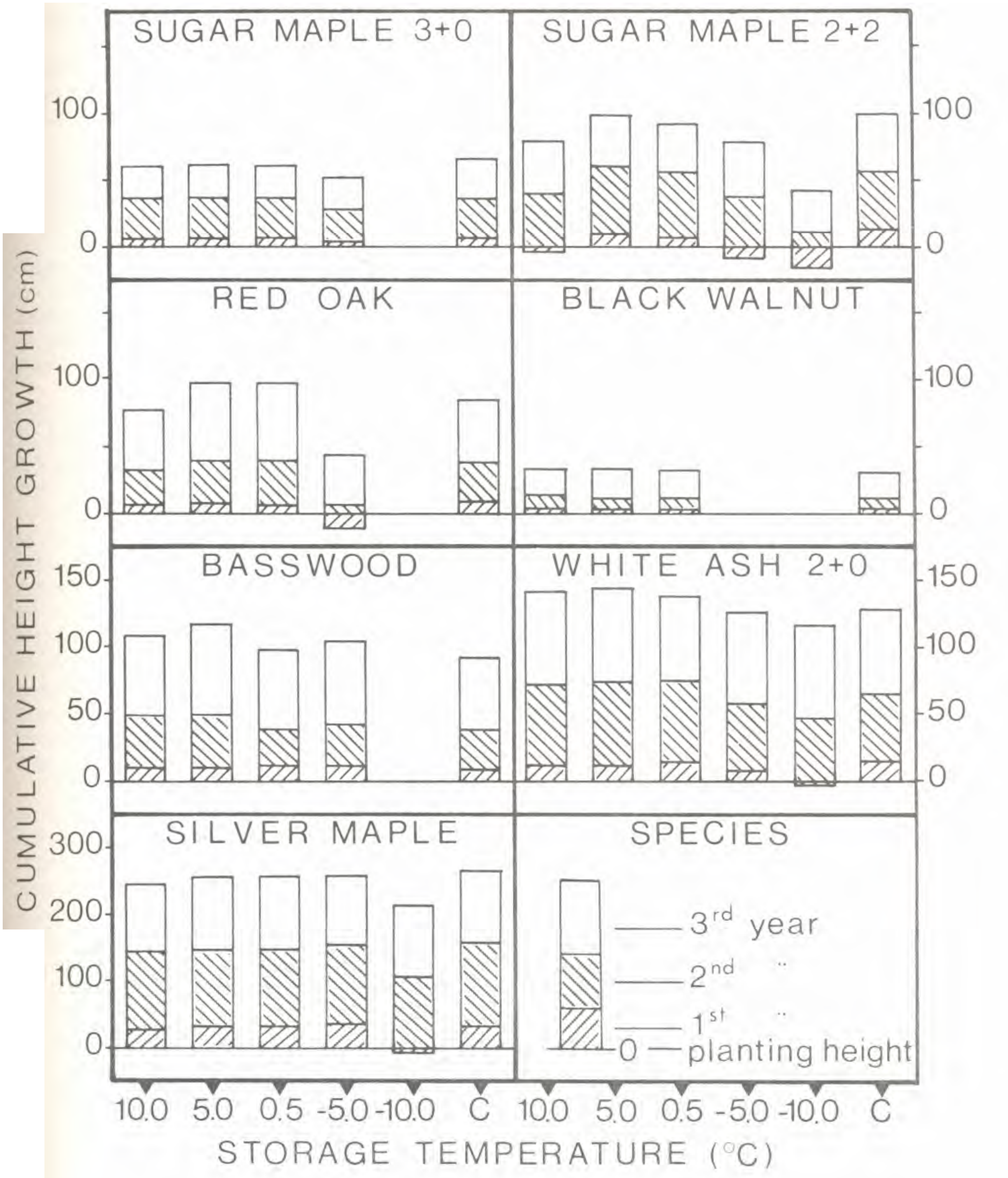

Figure 1. Cumulative height growth of species by cold storage temperature.

red oak seedlings (Table 3). However, third year height growth of seedlings stored at 0.5 and 5°C was significantly greater than that of seedlings stored at -5°C.

Second year height growth of basswood seedlings stored at 5 and 10°C was significantly greater than that of seedlings stored at 0.5 and -5°C (Table 4). First and third year height growth were not affected by storage temperature.

First year height growth of the 3+0 sugar maple seedlings was significantly lower following storage at -5°C than at 0.5 and 5°C (Table 6). Second and third year height growth were unaffected by storage temperature.

First year height growth of the few surviving sugar maple transplants stored at -10°C was significantly lower than that of trees stored at all other temperatures and the control (Table 7). This difference was less pronounced in the second year and the difference had disappeared completely in the third year.

With the exception of the 2+2 sugar maple transplants no significant difference in first year height growth was found between trees of all species stored at 0.5 and 5°C and the fresh-planted stock. Thus, stock stored at 0.5 and 5°C grew as well as or better than spring-lifted nursery stock.

As in previous studies with sugar maple, height growth was closely correlated with root growth capacity, and this indicates that adequate root extension is a prerequisite for good height growth.

Method of packaging had no effect on the height growth of red oak, basswood, black walnut and sugar maple seedlings (Table 8). Second and third year height growth of white ash seedlings was significantly lower in packaging treatment one than in the other two treatments. First year height growth of silver maple seedlings and second year height growth of sugar maple transplants was significantly lower in treatment three than in the other two treatments.

Since packaging method had no effect on root growth capacity or survival of any species and the few significant differences in height growth show no definite trend, it is apparent that all packaging methods listed in this experiment were equally efficient in maintaining tree viability. A further experiment has been established to determine the effect of other packaging methods in combination with a range of storage humidities on tree survival and growth.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study show that white ash, silver maple, red oak, basswood, and black walnut seedlings and sugar maple seedlings and transplants stored over winter at temperatures of 0.5 and 5°C survived and grew as well as spring-lifted and fresh-planted seedlings and transplants. Previous experiments have shown that sugar maple, cold-stored over winter, allowed the extension of the planting season into June without loss of shoot growth (von Althen and Webb 1978).

Although further studies are necessary to confirm that overwinter cold storage will allow the extension of the planting season for white ash, silver maple, red oak, basswood and black walnut, overwinter cold storage promises to become a most useful tool for nurserymen and field planters to ease the labor strain during the short spring planting season. In addition, extension of the planting season will make possible the afforestation or reforestation of areas which are inaccessible or difficult to plant during the most favorable part of the spring planting season.

It is recommended that fall-lifted nursery stock of white ash, silver maple, red oak, basswood and sugar maple be cold stored at a temperature of 0.5°C and black walnut at 5°C with a relative humidity of 70-85%. Roots should be surrounded by moist peat and the total seedling tightly enclosed within a Kraft bag with a polyethylene liner.

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Table 1. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 2+0 white ash

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	149*a†	99a	98a	98a	42b	12a	59	71	142
+ 5	146a	100a	99a	99a	46b	13a	61	70	144
+ 0.5	114a	100a	100a	100a	44b	14a	61	63	138
- 5	50b	87b	73b	71b	45b	6b	49	68	123
- 10	0	9c	5c	5c	44/40b‡	1b	51	69	121
fresh planted	136a	100a	94a	94a	57a	14a	50	62	126

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

‡ Stem dieback

Table 2. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 2+0 silver maple

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			Total
		1978	1979	1980		1978	1979	1980	
+ 10	118*a†	100a	100a	100a	66a	28b	114ab	104	246
+ 5	118a	100a	100a	100a	69a	33ab	115ab	107	255
+ 0.5	108a	100a	100a	100a	68a	31ab	119ab	110	260
- 5	70b	100a	100a	100a	66a	34ab	118ab	106	250
- 10	2c	53b	53b	53b	68/50b‡	17c	109b	106	232
fresh planted	97ab	100a	100a	100a	70a	34ab	125a	106	265

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

‡ Stem dieback

Table 3. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 2+0 red oak

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	15*ab†	96a	91a	90a	24a	5	27	44ab	76
+ 5	12b	97a	94a	92a	26a	7	33	55a	95
+ 0.5	21a	98a	94a	94a	24a	6	33	58a	97
- 5	1c	38b	31b	30b	25/9c‡	6	17	37b	60
- 10	0	0	0	0	0	0	0	0	0
fresh planted	20ab	100a	97a	97a	17b	9	28	49ab	86

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

‡ Stem dieback

Table 4. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 2+0 basswood

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	64*a†	100a	94	92ab	29c	10	38a	60	108
+ 5	52a	99a	93	87ab	33bc	12	38a	64	114
+ 0.5	52a	98a	92	82b	36ab	11	27b	55	93
- 5	16b	88b	84	83ab	31bc	12	28b	63	103
- 10	1b	0	0	0	0	0	0	0	0
fresh planted	68a	100a	98	98a	42a	8	29ab	55	92

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

Table 5. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 1+0 black walnut

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	42*a†	96	81a	80a	24	3	10	33	46
+ 5	42a	97	84a	81a	25	2	9	32	43
+ 0.5	22b	94	67b	63b	25	2	7	33	42
- 5	0c	0	0	0	0	0	0	0	0
- 10	0c	0	0	0	0	0	0	0	0
fresh planted	13bc	100	87a	82a	28	2	7	31	40

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

Table 6. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 3+0 sugar maple

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	8*b†	96a	96	96	24	5ab	29	24	58
+ 5	64a	99a	96	94	24	7a	30	24	61
+ 0.5	61a	98a	97	94	23	7a	29	24	60
- 5	7b	100a	92	90	23	4b	25	25	54
- 10	0	3b	0	0	23	-	-	-	-
fresh planted	84a	100a	100	100	26	6ab	31	29	66

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

Table 7. Effect of overwinter storage temperature on root growth capacity, survival and height growth of 2+2 sugar maple

Storage temp.	Root growth capacity	Survival (%)			Ht. at time of planting	Ht. growth (cm)			
		1978	1979	1980		1978	1979	1980	Total
+ 10	0* †	94a	94a	94a	80/71‡bc	7b	46ab	38	91
+ 5	67a	100a	100a	100a	75b	10ab	50a	38	98
+ 0.5	91a	98a	98a	98a	86ab	8b	49a	36	93
- 5	19b	100a	96a	96a	80/63c	9ab	45ab	39	93
- 10	0	37b	37b	37b	80/64bc	1c	12b	30	43
fresh planted	143a	100a	100a	100a	91a	13a	43ab	43	99

* Mean numbers of new lateral roots produced after 30 days' growth in greenhouse conditions

† Means followed by the same letters are not significantly different

‡ Stem dieback

Table 8. Effect of method of packaging on the height growth of hardwood seedlings and transplants

Species and age class	First year ht. growth (cm)			Second year ht. growth (cm)			Third year ht. growth (cm)		
	Packaging treatment			Packaging treatment			Packaging treatment		
	1	2	3	1	2	3	1	2	3
2+0 white ash	11	11	11	53b	57ab	65a	61b	71a	72a
2+0 silver maple	31a	32a	26b	118	115	113	109	106	104
2+0 red oak	7	6	6	30	29	30	50	48	55
2+0 basswood	11	11	11	36	31	32	62	57	62
1+0 black walnut	2	2	3	9	8	9	34	32	32
3+0 sugar maple	5	6	6	28	29	27	24	25	23
2+2 sugar maple	9	8	7	52a	49a	41b	36	40	38

Within species and years means followed by different letters are significantly different