# EFFECTS OF PACKAGING METHODS ON THE SURVIVAL AND GROWTH OF COLD-STORED HARDWOOD PLANTING STOCK

by

F.W. von Althen and D.P. Webb[1]

## INTRODUCTION

Lifting of hardwood planting stock in late autumn followed by overwinter cold storage provides the following advantages over conventional spring lifted and fresh planting: (1) it assures a high degree of establishment success by maintaining high root regeneration capacity and overall seedling growth potential (Webb 1976, 1977); (2) it extends the planting season without decreased survival or growth (von Althen and Webb 1978); (3) it permits the work to be carried out when weather and soil conditions are favourable; (4) it permits nursery and field work to be spread over longer periods, thereby providing employment for fewer, but better trained workers; (5) it permits earlier and more accurate inventory of available stock; and (6) it allows timing of deliveries to coincide with planting site readiness and planting crew availability (Rietveld and Williams 1981).

In earlier experiments the range of suitable storage temperatures and their effect on the root growth capacity of stored hardwood seedlings were determined (Webb and von Althen 1980, von Althen and Webb 1981). The present paper outlines an experiment on the effects of various packaging methods on root growth capacity and three-year survival and growth of six commonly planted hardwood species in southern Ontario.

## METHOD

In November 1978, 2+0 white ash (*Fraxinus americana* L.), sugar maple (*Acer saccharum* Marsh), silver maple (*Acer saccharinum* L.), red oak (*Quercus rubra* L.), white birch (*Betula papyrifera* Marsh.), and 1+0 black walnut (*Juglans nigra* L.) were lifted at the Ontario Ministry of Natural Resources tree nursery, St. Williams, Ontario, and transported to Sault Ste. Marie, Ontario. All stock was leafless and dormant at time of lifting. All seedlings were graded for size and randomly allocated to one of the following five packaging treatments:

1. Seedlings were stored bare root with no coverings.

2. Seedling roots were enclosed in plastic-lined Kraft bags. The bags were sealed around the stems just above the root collars.

3. Seedling roots were packed in moist peat, and enclosed in plastic-lined Kraft bags. The bags were sealed around the stems just above the root collars,

[1] F.W. von Althen and D.P. Webb - Research Scientists, Great Lakes Forest Research Centre, Canadian Forestry Service, Sault Ste. Marie, Ontario P6A 5M7

4. Seedling roots were packed in moist peat with seedlings totally enclosed in plastic-lined Kraft bags.

5. Seedling roots were packed in moist peat, wrapped in wax paper, and enclosed in burlap.

Black walnut seedlings were stored at 5°C and a relative humidity of 84%. All other species were stored at 0.5°C and a relative humidity of 71% (Webb and von Althen 1980).

In April, 1979 all seedlings were removed from storage. At the same time comparable nursery stock of each species, except white birch, was lifted from nursery beds at St. Williams, Ontario and a sample was transported to Sault Ste. Marie. Eight seedlings from each packaging treatment and the spring-lifted control were planted in plastic pots and placed in a greenhouse under extended photoperiods of 16 hours and a temperature of approximately 18°C (night) and 28°C (day). The seedlings were observed for the number of new white lateral roots that had formed during storage, for the presence of terminal and lateral bud swell, and for the presence of fungal growth. Xylem water potential was determined on the terminal 10 cm of the shoot and on one main lateral root per seedling by means of the pressure chamber technique of Scholander et al. (1965). After 30 days in the greenhouse, root growth capacity measurements were obtained by counting the number of new white first and second order lateral roots.

All other seedlings were planted in former fields in southern Ontario within 3 days of removal from cold storage or lifting from nursery beds. White ash and silver maple were planted near Shipka in Stephan Township, Huron County. 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%. Sugar maple and white birch were planted near Parkhill, McGillivray Township, Middlesex County. The soil was well drained loam over clay loam at a depth of 40 to 60 cm. The pH of the plow layer was 6.8 and the organic matter content was 2.8%. Red oak was planted near Goderich, in Goderich Township, Huron County. The soil was well drained sandy loam over sand at a depth of 50 to 70 cm. The pH of the plow layer was 7.0 and the organic matter content was 1.5%. Black walnut was planted near Hornby in Esquesing Township, Halton County. The soil was imperfectly drained clay loam over clay at a depth of 45 to 50 cm. The pH of the plow layer was 6.8 and the organic matter content was 2.5%.

All fields had been plowed and disked in the summer of 1978. All seedlings were machine-planted at a spacing of 3 m between rows and 1.5 m within rows.

Weed control in the first year consisted of rototilling between the rows and spraying the unwanted vegetation within rows with 2 kg active ingredient/ha glyphosate. In the second and third year simazine was broadcast over all plantations at a dosage of 4 kg a.i./ha.

All species, except white birch, were planted in randomized block arrangements with 16 seedlings in each of six treatments (five packaging treatments plus the spring-lifted control). Each treatment was replicated three times for a total planting of 288 seedlings per species. White birch was planted in only the five packaging treatments for a total of 240 seedlings. Survival and height were recorded at the end of each of the first three growing seasons and the third-year data were subjected to analyses of variance. Significance of means (p 0.05) was identified by Tukey's procedure. Non-measurement data were subjected to Chi-square tests of significance.

## RESULTS AND DISCUSSION

### Greenhouse studies

The results of the greenhouse studies have been published (Webb and von Althen 1980). To review briefly: Bud swell and new root initiation during storage were minimal over all treatments and were confined to seedlings of sugar maple and silver maple. Fungal growth in storage was not a problem.

Significant differences in shoot and root xylem water potential were observed between packaging treatments in all species tested (Webb and von Althen 1980). Seedlings enclosed in plastic-lined Kraft bags with roots packed in moist peat exhibited the least amount of shoot water stress, and generally did not differ significantly from the spring-lifted controls. Seedlings stored bare root, with both roots and stems exposed to the storage environment, exhibited the greatest shoot water stress.

Seedlings enclosed within bags with their roots surrounded by moist peat produced the highest number of new roots after 30 days' growth in the greenhouse (Tables 1-5). Root growth capacity of seedlings in this treatment was equal to or higher than that of spring-lifted control stock. Most species showed no significant differences between treatments that enclosed the total seedling or root portion of the seedling within the bag, with or without peat. However, with white birch significantly greater root growth capacity was observed for seedlings stored enclosed entirely within the bag and with moist peat surrounding the roots than in seedlings stored in the other treatments (Table 6). This result was probably due to the large size of the white birch seedlings which resulted in the exposure of a large part of the stems to the drying conditions of the storage experiment.

### Survival

Packaging methods significantly affected the survival of all species (Tables 1-6). Bare-root storage (treatment 1) was detrimental to all species. Packing the roots in moist peat and wrapping them in wax paper and burlap (treatment 5) caused mortality of all red oak and white birch seedlings, significantly reduced the survival of sugar maple and silver maple seedlings, but had no effect on the survival of white ash and black walnut seedlings. Packing the seedling roots in bags with or without peat or totally enclosing the seedlings in bags with moist peat surrounding the roots (treatments 2, 3 and 4) provided

92% or better survival of all species except white birch. White birch survival was much better for seedlings totally enclosed in bags than for those with only their roots enclosed. Survival of all species was closely correlated with root growth capacity, an indication that adequate root extension is a prerequisite for satisfactory survival.

Mortality in years two and three was relatively minor for all species and treatments except white birch. The second year mortality of white birch in treatment three was most likely caused by simazine damage after part of the simazine from the surrounding plots washed into one birch plot during a heavy rainstorm shortly after the simazine application.

Height growth

Apart from the treatments which resulted in the mortality of all, or nearly all seedlings, packaging method had no effect on the three-year height growth of any species except black walnut. Even for black walnut, however, the difference in growth between the cold-stored and spring-lifted seedlings was most likely the result of difference in planting stock rather than treatment effect. The black walnut seedlings lifted in spring came from a different seedbed than the cold-stored seedlings, and were taller but much more spindly than the cold-stored stock (Table 5).

Although packaging treatments had little effect on three-year height growth, they caused severe stem dieback in several species and thereby affected total height; The few seedlings which survived the bare-root storage (treatment 1) died back and resprouted from the root collar. Enclosure of the roots in plastic-lined Kraft bags but no peat (treatment 2) caused dieback of white birch stems to approximately half wax paper and burlap (treatment 5) caused severe stem dieback of sugar maple, silver maple and black walnut seedlings.

In this experiment no significant differences were found in height growth or total height of any species between treatments 3 and 4. However, in a different experiment large silver maple seedlings stored in bags with moist peat surrounding their roots, but with their tops protruding from the bags, suffered stem dieback (unpublished data). In contrast, smaller silver maple of the same seedlot, with their stems totally enclosed in the bags, suffered no dieback.

These findings together with the results of measurements of shoot and root xylem water potential suggest that the best packaging method is the packing of seedling roots in moist peat and enclosure of the total seedling in Kraft bags with plastic liners.

## CONCLUSIONS AND RECOMMENDATIONS

The results of this study and previous studies (Webb 1976, 1977, von Althen and Webb 1980, 1981, Webb and von Althen 1980, Rietveld and Williams 1981) show that white ash, sugar maple, silver maple, red oak, white birch and black walnut seedlings can be cold-stored over winter without loss of survival or height growth as long as the physiological requirements of the species are met. Studies have also 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). Further studies are in progress to test if overwinter cold storage allows the extension of the planting season for white ash, silver maple, red oak, white birch and black walnut seedlings. If these tests are successful, overwinter cold storage of these species will not only ease the labor strain on nurserymen and planting crews, but will also make possible the afforestation or reforestation of areas that are inaccessible or difficult to plant during the normal spring planting season.

The following recommendations are made for successful overwinter cold storage of white ash, sugar and silver maple, red oak, white birch and black walnut:

1. Lift stock in late autumn when seedlings are leafless and dormant.

2. Store white ash, sugar and silver maple, red oak, and white birch at 0.5°C and black walnut at 5°C with relative humidities of 70-85%.

3. Enclose total seedling in plastic-lined Kraft paper bags and surround roots with moist peat. To protect tall seedlings from desiccation during storage, place a plastic bag upside down over the tops of the stems protruding from the Kraft bag and tie both bags to prevent the escape of moisture.

4. Plant seedlings as soon as possible following removal from cold storage.

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Table 1. Three-year survival and height growth of cold-stored 2+0 white ash seedlings.

| Treatments | Root growth capacity | Survival (%) | | | Height at planting (cm) | Height growth (cm) | | | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1981 | | 1979 | 1980 | 1981 | | |
| 1. Bare root | 0*+ | 2 | 2 | 2 *y* | 36/1++ | 10 | 16 | 83 | 109 | 110 |
| 2. Roots in bag without peat | 88 *a* | 98 | 94 | 92 *x* | 36 | 11 | 39 | 67 | 117 | 153 |
| 3. Roots in bag with peat | 75 *ab* | 100 | 100 | 96 *x* | 37 | 11 | 30 | 64 | 105 | 142 |
| 4. Total seedlings in bag with peat | 69 *ab* | 100 | 98 | 98 *x* | 35 | 12 | 26 | 57 | 95 | 130 |
| 5. Roots in peat wrapped in wax paper and burlap | 53 *bc* | 98 | 98 | 98 *x* | 37 | 11 | 39 | 56 | 106 | 143 |
| 6. Spring-lifted | 40 *c* | 98 | 88 | 83 *x* | 24 | 10 | 29 | 52 | 91 | 115 |

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

+Measurements followed by the same letters are not significantly different.

++Stem dieback.

Table 2. Three-year survival and height growth of cold-stored 2+0 sugar maple seedlings.

| Treatments | Root growth capacity | Survival (%) | | | Height at planting (cm) | Height growth (cm) | | | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1981 | | 1979 | 1980 | 1981 | | |
| 1. Bare root | 0 *c* *+ | 0 | 0 | 0 | - | - | - | - | - | - |
| 2. Roots in bag without peat | 66 *a* | 96 | 96 | 96 *x* | 37 | 6 | 25 | 36 | 67 | 104 |
| 3. Roots in bag with peat | 46 *b* | 100 | 100 | 98 *x* | 41 | 5 | 26 | 36 | 67 | 108 |
| 4. Total seedlings in bag with peat | 52 *ab* | 100 | 96 | 94 *x* | 45 | 10 | 19 | 34 | 63 | 108 |
| 5. Roots in peat wrapped in wax paper and burlap | 6 *c* | 88 | 85 | 81 *y* | 41/7++ | 15 | 22 | 23 | 60 | 67 |
| 6. Spring-lifted | 44 *b* | 98 | 98 | 98 *x* | 39 | 6 | 24 | 30 | 60 | 99 |

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

+Measurements followed by the same letters are not significantly different.

++Stem dieback.

Table 3. Three-year survival and height growth of cold-stored 2+0 silver maple.

| Treatments | Root growth capacity | Survival (%) | | | Height at planting (cm) | Height growth (cm) | | | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1981 | | 1979 | 1980 | 1981 | | |
| 1. Bare root | 27 *b* *+ | 0 | 0 | 0 *y* | – | – | – | – | – | – |
| 2. Roots in bag without peat | 30 *b* | 100 | 100 | 100 *x* | 74 | 40 | 92 | 78 | 210 | 284 |
| 3. Roots in bag with peat | 66 *a* | 100 | 100 | 100 *x* | 63 | 40 | 85 | 90 | 275 | 278 |
| 4. Total seedlings in bag with peat | 70 *a* | 100 | 100 | 100 *x* | 72 | 42 | 91 | 95 | 228 | 300 |
| 5. Roots in peat wrapped in wax paper and burlap | 256 | 19 | 19 | 19 *y* | 76/1++ | 40 | 56 | 75 | 171 | 172 |
| 6. Spring-lifted | 61 *a* | 100 | 100 | 100 *x* | 63 | 34 | 74 | 89 | 197 | 260 |

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

+Measurements followed by the same letters are not significantly different.

++Stem dieback.

Table 4. Three-year survival and height growth of cold-stored 2+0 red oak seedlings.

| Treatments | Root growth capacity | Survival (%) | | | Height at planting (cm) | Height growth (cm) | | | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1981 | | 1979 | 1980 | 1981 | | |
| 1. Bare root | 0 *d* *+ | 0 | 0 | 0 *z* | - | - | - | - | - | |
| 2. Roots in bag without peat | 7 *bc* | 98 | 98 | 94 *xy* | 50 | 12 | 16 | 26 | 54 | 104 |
| 3. Roots in bag with peat | 15 *a* | 96 | 96 | 94 *xy* | 59 | 16 | 11 | 27 | 54 | 113 |
| 4. Total seedlings in bag with peat | 11 *ab* | 100 | 100 | 100 *x* | 57 | 15 | 18 | 35 | 68 | 125 |
| 5. Roots in peat wrapped in wax paper and burlap | 0.4 *cd* | 0 | 0 | 0 *z* | - | - | - | - | - | - |
| 6. Spring-lifted | 4 *bcd* | 94 | 94 | 88 *y* | 36 | 12 | 10 | 30 | 52 | 88 |

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

+Measurements followed by the same letters are not significantly different.

+

+Stem dieback.

Table 5. Three-year survival and height growth of cold-stored 1+0 black walnut.

| Treatments | Root growth capacity | Survival (%) 1979 | Survival (%) 1980 | Survival (%) 1981 | Height at planting (cm) | Height growth (cm) 1979 | Height growth (cm) 1980 | Height growth (cm) 1981 | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Bare root | 0 *b* *+ | 0 | 0 | 0 *y* | - | - | - | - | - | - |
| 2. Roots in bag without peat | 22 *a* | 100 | 96 | 96 *x* | 24 | 7 | 21 | 45 | 73 *ab* | 97 |
| 3. Roots in bag with peat | 18 *a* | 100 | 92 | 92 *x* | 28 | 7 | 19 | 53 | 79 *a* | 107 |
| 4. Total seedlings in bag with peat | 17 *a* | 100 | 100 | 94 *x* | 25 | 6 | 20 | 53 | 79 *a* | 104 |
| 5. Roots in peat wrapped in wax paper and burlap | 12 *ab* | 100 | 96 | 94 *x* | 25/16++ | 8 | 23 | 50 | 81 *a* | 97 |
| 6. Spring-lifted | 16 *a* | 10 | 98 | 98 *x* | 53 | 5 | 8 | 42 | 55 *b* | 108 |

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

+Measurements followed by the same letters are not significantly different.

++Stem dieback.

Table 6. Three-year survival and height growth of cold-stored 2+0 white birch.

| Treatments | Root growth capacity | Survival (%) | | | Height at planting (cm) | Height growth (cm) | | | Three-year height growth (cm) | Total height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1981 | | 1979 | 1980 | 1981 | | |
| 1. Bare root | 0.3 *b* | 6 | 6 | 6 *z* | 90/2+ + | 20 | 60 | 40 | 118 | 122 |
| 2. Roots in bag without peat | 8 *a* | 60 | 60 | 60 *y* | 89/40 | 27 | 37 | 67 | 131 | 171 |
| 3. Roots in bag with peat | 12 *a* | 81 | 69 | 67 *y* | 82 | 18 | 42 | 63 | 123 | 205 |
| 4. Total seedlings in bag with peat | 28 | 96 | 92 | 92 *x* | 102 | 25 | 32 | 65 | 122 | 224 |
| 5. Roots in peat wrapped in wax paper and burlap | 7 *ab* | 0 | 0 | 0 *z* | – | – | – | – | – | – |

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

+Measurements followed by the same letters are not significantly different.

+
+Stem dieback.