HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

Effect of Transplanting on Shoot Water Potential of Bare-root Washington Hawthorn and Norway Maple Trees[1]

Rick M. Bates[2] and Alexander X. Niemiera[3]
Department of Horticulture
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0327

Abstract

Two-year-old Norway maple (*Acer platanoides* L.) and Washington hawthorn (*Crataegus phaenopyrum* Med.) trees were cold-stored for 2, 4, 6, 8, 10, and 12 weeks and stem water potentials were measured prior to and five days after transplanting. In a second experiment, a wax coating was applied to hawthorn trees at transplanting and shoot water potential was measured at two-day intervals for twelve days after transplanting; percent bud break was measured eight weeks after transplanting. In a third experiment, maple and hawthorn trees were stored for 2, 4, 6, 8, 10, and 12 weeks with the following tree covering treatments: whole plant covered, shoots exposed, roots exposed, and whole plant exposed, and root hydraulic conductivity was measured for each storage duration. For each storage duration, maple stem water potentials after transplanting were the same as or higher than the pre-transplant potential value; hawthorn water potentials after transplanting were generally lower than pre-transplant values. Six to eight days after transplanting, hawthorn water potentials of wax covered stems were higher than unwaxed stems. Bud break percentages were higher for trees with waxed stems than for trees without wax. Root hydraulic conductivity was the same for both species and decreased with increased storage duration and for treatments exposing roots.

Index words: *Acer platanoides, Crataegus phaenopyrum*, water stress, cold storage, hydraulic conductivity, desiccation, wax coating.

Significance to the Nursery Industry

In producing trees from bare root whips, some species, such as Washington hawthorn, have low post-transplant survival rates due to desiccation. In contrast, desiccation tolerant species, such as Norway maple, readily recover from desiccation. For desiccation sensitive species, coating stems with wax following cold storage prior to transplanting alleviates post-transplant water stress. Therefore, applying an anti-desiccant wax to stems prior to transplanting is recommended to increase survival rates of desiccation sensitive species.

[1]Received for publication September 5, 1995; in revised form December 4, 1995. We wish to recognize and thank the Virginia Nurserymen's Association for funding this research.

[2]Assistant Professor, Department of Plant, Soil & Environmental Sciences, Montana State University, Bozeman, MT.

[3]Associate Professor.

Introduction

Desiccation of bare-root nursery stock during storage and after transplanting can result in poor regrowth and is considered to be the main cause of post-transplant tree death (4, 7, 8). Several studies have shown that tree species differ widely in their response to storage conditions (6, 12), temperature (13), and duration (10). Bates and Niemiera (1) found that, following storage and transplanting into a moist substrate, stem xylem water potentials (Ψ_s) increased (be-

The *Journal of Environmental Horticulture* (USPS Publication No. 698-330) is published quarterly in March, June, September, and December by the Horticultural Research Institute. Subscription rate is $65.00 per year for educators and scientists; $85.00 per year for others; add $25.00 for international orders. Second-class postage paid at Washington, D.C. and at additional mailing office. Send address changes to HRI, 1250 I Street, N.W., Suite 500, Washington, D.C. 20005.

came less negative) for Norway maple (*Acer platanoides*), but decreased for Yoshino cherry (*Prunus* x *yedoensis*), which resulted in more stem dieback and reduced survival for cherry compared to maple. These results suggested species differences in stem water loss rates, root water absorption and conductivity, or a combination of these factors. Sulaiman (11) found differences in the rate of water loss through the defoliated stems of *Quercus alba* L. and *Fraxinus pennsylvanica* Marsh., however, there are no reports on the contribution of stem water loss and root hydraulic conductivity (J_v) to decreasing Ψ after transplanting. Objectives of this study using bare-root trees were to 1) determine the influence of storage duration on the post-transplant Ψ_s of desiccation sensitive *Crataegus phaenopyrum* and desiccation tolerant *Acer platanoides*, 2) determine how J_v was influenced by cold storage duration and treatments, and 3) determine if post-storage stem wax coating influenced Ψ_s and bud break.

Materials and Methods

Storage duration and Ψ. On January 14, 1993, 2-year-old bare-root *Acer platanoides* and *Crataegus phaenopyrum* seedlings 60–90 cm (24–36 in) tall were received in Blacksburg, VA, from Lawyer Nurseries, Plains, MT. During the five day shipping period seedlings were wrapped in plastic sheeting and placed in cardboard boxes with the roots of each bundle packed in moistened, shredded newsprint. Upon arrival, trees were sorted for uniformity, enclosed in storage bags (Union Camp Corp., Tifton, GA.) to reduce water loss, and placed on wooden racks in a walk-in cooler maintained at 70% ± 5% relative humidity and 2C (35F). On January 28, February 11, February 28, March 11, March 28, and April 11, (2, 4, 6, 8, 10 and 12 weeks in storage, respectively) 16 hawthorn and 16 maple trees were randomly selected and removed from cold storage. Stem water potential was measured between 1200 and 1400 HR the same day using a portable pressure chamber (Model 3005, SoilMoisture Equipment Corp., Santa Barbara, CA) on a 10.2 cm (4 in) stem section excised from 8 trees of each species. The remaining trees were transferred to a greenhouse ventilated at 24C (75F) and heated at 18C (64F), transplanted into 100% pine bark-filled 3.8 liter (1 gal) plastic containers and thoroughly irrigated. Stem water potential was then measured between 1200 and 1400 HR for these trees five days after transplanting. Storage duration and time of measurement factors were applied in a completely randomized design with eight single plant replications. Data were subjected to analysis of variance (ANOVA) and mean comparisons were made using a *t* test. Species (maple and hawthorn) data were analyzed separately.

Storage treatment and root hydraulic conductivity. Plant material was identical to that used in the above experiment except that at the time seedlings were placed into cold storage, one of the following treatments was randomly allocated to each tree: 1) 'whole plant covered' in which the entire seedling was enclosed in a sealed 3-layer storage bag (Union Camp Corp., Tifton, GA.), 2) 'shoot exposed' in which seedling roots were enclosed in a storage bag sealed around the stem just above the root collar, 3) 'roots exposed' in which shoots were enclosed in a storage bag sealed just below root collar and 4) 'entire seedling exposed' (no storage bag). Storage bags were compressed during plant insertion to minimize air space within the bag; all trees were placed horizontally on racks. On January 28, February 11, February 28, March 11, March 28 and April 11, six hawthorn and six maple trees from each treatment were removed from cold storage and J_v was measured on three seedlings from each species × treatment combination. The remaining three seedlings from each combination were placed on a lab bench and air-dried at 24C (75F) and 35% ± 5% relative humidity for 12 hr. For J_v determinations, 15.3 cm (6 in) excised primary lateral roots from each plant were submerged in distilled water; cortical tissue at the proximal end of the root was trimmed exposing the stele which was inserted into a section of Tygon tubing and fastened with a silicon washer. Root and tubing were mounted into the lid orifice of a pressure chamber with the proximal root end protruding through a gasket. The distal portion of the root system was immersed in a water-filled plastic container located in the pressure vessel. Water temperature was maintained at 20C (68F). Hydrostatic pressure was slowly increased to 0.5 MPa using compressed air. The volume of water that exited the cut root surface was measured with a pipette attached to the tubing. Water flow rates through tubing were recorded at 5-minute intervals until the change in flow rate over time was the same for a minimum of three readings, which indicated the system had reached equilibrium. The volume of water flow (flux) at equilibrium was expressed on a root dry weight basis. Data were subjected to analysis of variance (ANOVA). Species and cold storage treatments were replicated three times using a completely randomized design. Desiccation

Table 1. Influence of cold storage duration on shoot water potential of pre- and post-transplant 2-year-old Washington hawthorn and Norway maple.

		Shoot Ψ (–MPa)					
		Storage duration (weeks)					
Measurement time	Initial[z]	2	4	6	8	10	12
Maple							
Pre-transplant	0.90	0.92a[y]	1.14a	1.25a	1.55a	1.80a	1.84a
5 days post-transplant		0.75a	0.95a	1.15a	1.20b	1.40b	1.45b
Hawthorn							
Pre-transplant	1.10	1.45a	1.85a	1.92a	1.84a	1.93a	2.25a
5 days post-transplant		1.82b	2.10a	2.27b	2.23b	2.30b	2.41a

[z]Pre-storage Ψ_s.

[y]Mean separation by t test at P = 0.05. Same letter within column (by species) indicates no significant difference, n = 8.

time (0 hr vs. 12 hr) and storage duration data were analyzed separately. Slope of the least squares was determined for storage treatments over storage duration.

Stem wax treatment. Dormant 2-year-old *Crataegus phaenopyrum* bare-root seedlings were received from Lawyer Nurseries, Plains, MT, on February 16, 1994, and placed in cold storage maintained at 90% relative humidity and 2C (35F). Within storage, 78 trees were enclosed in storage bags (entire plant bagged; approx. 10 trees/bag) and 78 trees were unbagged. On February 24, 78 seedlings from each group (bagged and unbagged) were removed from storage and Ψ_s was measured between 1200 and 1400 HR on six trees of each group. The entire shoot system of 36 trees per storage treatment group were submerged in melted TissuePrep (Fisher Scientific Co., Fair Lawn, NJ) paraffin and then dipped into cold water to solidify the wax. The remaining 36 uncoated trees from each group served as the control. All seedlings were then immediately transplanted into 100% pine bark-filled 3.8 liter (1 gal) containers and placed on raised benches in a greenhouse which was ventilated at 24C (75F) and heated at 18C (64F). Shoot water potentials were measured between 1200 and 1400 HR on six trees from the wax treated and untreated controls 2, 4, 6, 8, 10, and 12 days after transplanting. Percent bud break (number of growing buds/total bud number) was measured for each tree 8 weeks after transplanting. Plants in the stem wax treatment and time after transplanting treatments were arranged using a completely randomized design replicated six times. Data were subjected to analysis of variance (ANOVA) and mean comparisons were made using the *t* test. Storage treatment (bagged and unbagged) data were analyzed separately.

Results and Discussion

Storage duration and Ψ. Pre-transplant maple Ψ_s decreased with increasing cold storage duration (Table 1). This affect of storage duration on Ψ_s was the same as found by Bates (2) in a previous study. For the first six weeks in storage, pre-transplant maple Ψ_s were ≥ -1.2 MPa. Post-transplant Ψ_s values were the same as the respective pre-transplant values for the first six weeks in storage. After eight weeks in storage, pre-transplant values were ≤ -1.5 and post-transplant Ψ_s were higher than the respective pre-transplant values. For hawthorn, Ψ_s decreased more rapidly during storage than maple, reaching a low of –2.25 MPa after twelve weeks (Table 1). Also in contrast to maple, post-transplant Ψ_s were lower than respective pre-transplant values for four of the six durations. In a similar study, Bates and Niemiera (1) reported post-transplant recovery from water stress for Norway maple and lack of recovery for the desiccation sensitive Yoshino cherry. Post-transplant recovery or the lack of recovery from pre-transplant induced water stress may be related to water absorption by roots, conductivity of the pre-bud break root system, stem water loss characteristics, or a combination of these factors.

Storage treatment and root hydraulic conductivity. Root hydraulic conductivity values were the same for both species within each post-storage desiccation treatment ($P = 0.05$, data not shown). Root hydraulic conductivity (averaged over species) for trees (0 hr desiccation treatment) decreased rapidly with increased storage duration for roots exposed (slope = –5.03) and whole plant exposed treatments (slope = –4.06) (Fig. 1). Compared to the roots exposed and whole plant exposed treatments, the decrease in J_v was low for the shoots exposed (slope = –1.32) and entire seedling covered (slope = –1.43) treatments. At each storage duration, root hydraulic conductivity for roots exposed and entire seedling exposed treatments were less than for shoots exposed and entire seedling covered treatments. Relative to the 0 hr desiccation treatment, air drying trees for 12 hr greatly reduced water conductivity rates resulting in no differences between storage treatments (Fig. 1).

Root hydraulic conductivity data showed that water flow in roots of both species was very sensitive to the storage conditions of this study and a 12 hr exposure to ambient conditions (Fig. 1). Water stress in loblolly pine has been shown to reduce water absorption because of an apparent reduction in root cell permeability (3). The relatively large decrease in J_v after a 12-hr desiccation period indicated the necessity for growers to protect root systems of bare-root plants during planting. Results of this and other work (7)

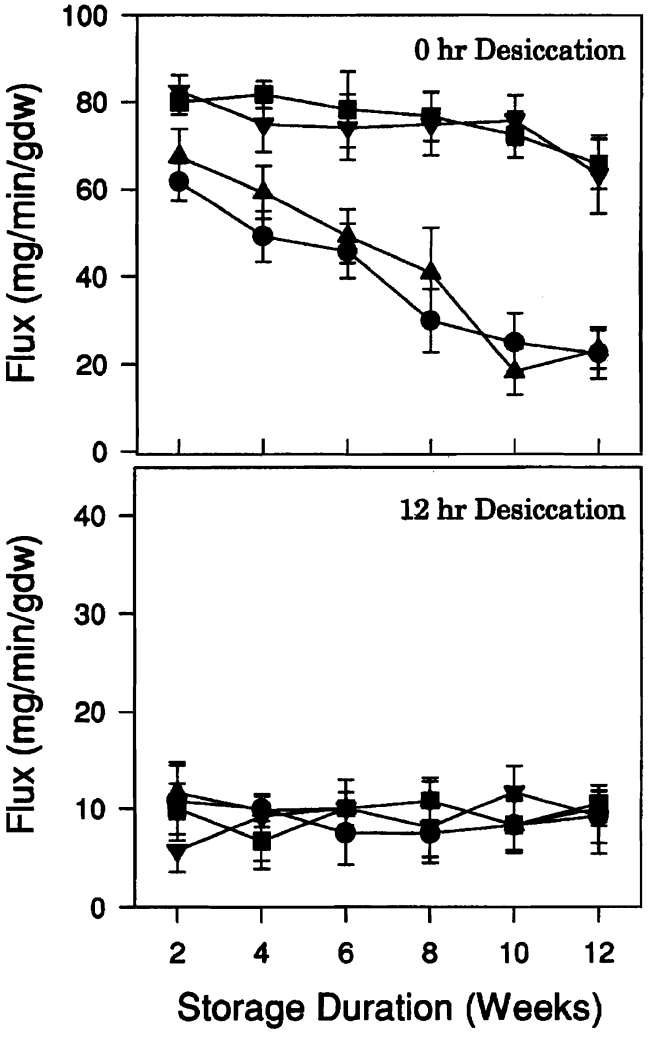

Fig. 1. Hydraulic conductivity (flux) of cold-stored hawthorn and maple seedling roots measured after 0 hr and 12 hr desiccation treatments. Storage treatments: whole plant exposed (●), roots exposed (▲), shoots exposed (▼), whole plant covered (■). Means averaged over species, n = 6. Vertical bars represent ± 1 SE, n = 6.

Table 2. Influence of wax coating on shoot water potential and bud break of unstressed (bagged in storage) and stressed (unbagged in storage) 2-year-old Washington hawthorn after transplanting.

	Shoot Ψ (–MPa)						
		Days after transplanting					
Stem treatment	Initial Ψ[z]	2	4	6	8	10	12	Bud break[y] (%)
Unstressed								
Wax coated	0.76a[x]	0.72a	0.69a	0.70a	0.60a	0.57a	0.55a	85a
No wax coating	0.74a	0.77a	0.90a	0.94a	1.00b	1.20b	1.25b	59b
Stressed								
Wax coated	1.82a	1.53a	1.15a	1.03a	0.98a	1.02a	1.13a	71a
No wax coating	1.77a	1.79a	1.88b	1.95b	2.02b	2.26b	2.25b	26b

[z]Stem water potential prior to transplanting.

[y]Average % bud break 8 weeks after transplanting (n = 6).

[x]Mean separation within columns by t test, P = 0.05. Means followed by the same letter are not significantly different, n = 6.

support the contention that roots of seedling nursery stock are extremely vulnerable to desiccation stress. The lack of differences in J_v between species, implied that the movement of water through roots was the same for desiccation sensitive and desiccation tolerant species. Hence, the difference in post-transplant Ψ_s responses between maple and hawthorn (Table 1) was apparently related to species specific stem water loss characteristics. In support of this contention, Bates (2) reported that hawthorn Ψ_s decreased more rapidly and to a greater extent during cold storage than Norway maple Ψ_s.

Stem wax treatment. Stem water potential for unwaxed hawthorn seedlings that were unstressed (covered) during storage decreased 69% during the twelve days after transplanting compared to a 28% decrease for the wax covered seedlings (Table 2). Thus, the wax covering greatly ameliorated post-transplant water stress. Bud break (percent of total buds emerging) for unstressed trees with wax-coated stems was 26% higher than for trees without the wax coating (Table 2). Stressed hawthorn seedlings (uncovered in storage) exhibited the same Ψ_s trends as unstressed seedlings (Table 2) although values were lower and differences between wax and no wax treatments occurred four days after transplanting compared to eight days for unstressed trees. This finding is in agreement with Murakami et al. (1990) who reported that hawthorn bud break decreased from 78% to 27% when Ψ_s decreased from –0.8 to –2.5 MPa. The wax coating data of the current work indicated that water exiting through hawthorn stem tissue was responsible for increasing water stress. The low bud break percentages for the unwaxed trees of both stressed and unstressed experiments demonstrated the lack of desiccation tolerance of hawthorn. From a commercial standpoint, bud break percentages for the unwaxed treatments are unacceptable.

In summary, we found that bare-root hawthorn water stress increased during cold storage more rapidly than maple. The desiccation sensitive nature of hawthorn is most likely related to water loss from stems since coating hawthorn stems with wax at transplanting minimized water stress and maximized bud break. We concluded that water flow in roots was not responsible for the sensitivity because there was no difference in J_v between hawthorn and maple. Survival rates for transplanted bare-root hawthorn trees are relatively low in the nursery industry. Thus, understanding the nature of desiccation sensitivity can be used to improve water relations during cold storage and after transplanting thereby increasing post-transplant survivability. From this and other work (2, 5), we recommend that the shoot and roots of desiccation sensitive species be enclosed in a bag during cold storage and that stems be treated with an antidesiccant at transplanting.

Literature Cited

1. Bates, R.M. and A.X. Niemiera. 1994. Mist irrigation reduces post-transplant desiccation of bare-root trees. J. Environ. Hort. 12:1–3.

2. Bates, R.M. 1994. Characterization of water stress during cold storage and establishment for *Acer platanoides* and *Crataegus phaenopyrum*. Ph.D. dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA.

3. Brix, H. 1960. Determination of viability of Loblolly pine seedlings after wilting. Bot. Gaz. 121:220–223.

4. Coutts, M.P. 1981. Effects of root or shoot exposure before planting on the water relations, growth and survival of Sitka spruce. Can. J. For. Res. 11:703–709.

5. Englert, J.M., K. Warren, L. Fuchigami, and T. Chen. 1993. Antidesiccant compounds improve the survival of bare-root deciduous nursery trees. J. Amer. Soc. Hort. Sci. 118:228–235.

6. Hermann, R.K. 1967. Seasonal variation in sensitivity of Douglas Fir seedlings to exposure of roots. Forest Sci. 13:140–149.

7. Insely, H. and G.P. Buckley. 1985. The influence of desiccation and root pruning on the survival and growth of broadleaved seedlings. J. Hort. Sci. 60:377–387.

8. Kozlowski, T.T. and W.J. Davies. 1975. Control of water balance in transplanted trees. J. Arboriculture 1:1–10.

9. Murakami, P., T.H. Chen, and L.H. Fuchigami. 1990. Desiccation tolerance of deciduous plants during postharvest handling. J. Environ. Hort. 8:22–25.

10. Ritchie, G.A., J.R. Roden, and N. Kleyn. 1985. Physiological quality of lodgepole pine and interior spruce seedlings: effect of lift date and duration of freezer storage. Can. J. For. Res. 15:636–645.

11. Sulaiman, A.S. 1968. A study of desiccation and the effects of antidesiccants on water loss through the foliage and bark of five species of hardwood planting stock. PhD Diss., North Carolina State Univ., Raleigh. (Diss. Abstr. 68_13479).

12. Tabbush, P.M. 1987. Effect of desiccation on water status and forest performance of bare-rooted Sitka spruce and Douglas Fir transplants. Forestry 60:31–43.

13. Webb, D.P. and F.W. von Althen. 1980. Storage of hardwood planting stock: effects of various storage regimes and packaging methods on root growth and physiological quality. New Zealand J. For. Sci. 10:83–89.