Effect of Cold Storage and Pre-transplant Desiccation on Root Growth Potential and Bud Break of Bare-root Washington Hawthorn and Norway Maple[1]

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Abstract

Two-year-old Washington hawthorn (*Crataegus phaenopyrum* Med.) and Norway maple (*Acer platanoides* L.) seedlings were subjected to varying cold storage durations and 4 storage treatments: whole plant covered, shoots exposed, roots exposed and whole plant exposed. After storage, half the seedlings were immediately planted and half received a 12-hr desiccation treatment prior to transplanting. Root growth potential (RGP), time to bud break, and marketability were measured. With the root covered treatments, Norway maple RGP increased, while Washington hawthorn RGP decreased with increased cold storage duration. RGP for both species remained low throughout storage for treatments exposing roots. The 12-hr desiccation treatment reduced RGP for both species with hawthorn being more affected than maple. Days to bud break for both species decreased with increased storage time for whole plant covered treatments, but increased for both species when stored with exposed roots. Maple marketability for root covered treatments was high for most storage durations. Hawthorn marketability was generally low except for the whole plant covered treatment during the first 6 weeks of storage. For the respective storage durations, hawthorn RGP, time to bud break and marketability values for the shoots exposed treatment were similar to the roots exposed treatments. In contrast, values for the shoot exposed treatment were similar to the whole plant covered treatment for maple. There was a high positive correlation between RGP and marketability for both species.

Index words: marketability, water stress, storage bags, root regeneration.

Species used in this study: Norway maple (*Acer platanoides* L.), Washington hawthorn (*Crataegus phaenopyrum* Med.).

Significance to the Nursery Industry

For bare root trees, minimizing the time from transplanting to bud break is important since bud break is associated with root growth and subsequent water uptake. For desiccation sensitive species such as Washington hawthorn, covering shoots as well as roots during storage minimizes the time from transplanting to bud break and increases the root growth potential. Covering only roots of desiccation sensitive species during storage increases the time to bud break and lowers the root growth potential (compared to covering the entire plant). For most species, current storage and handling practices are acceptable and post-transplant survival rates are high. Desiccation sensitive species such as Washington hawthorn, however, may require modified cultural practices during extended cold storage and after transplanting to ensure acceptable bud break and subsequent root growth.

Introduction

Rapid root regeneration is a critical factor in the successful establishment and survival of transplanted tree seedlings (13, 15, 18). Root growth potential (RGP), defined as the ability of a bare-root seedling to grow roots when placed in a favorable environment (12), has been positively correlated with field performance for numerous conifers (6, 10, 11, 16) and deciduous trees (17, 19). Such trees with relatively high RGP's are able to quickly exploit water and nutrients beyond the original planting hole, thus hastening establishment.

Bare-root trees are commonly dug in late fall, placed in cold storage, and shipped and replanted in the spring. Trees handled in this manner are subject to desiccation until replanting is accomplished. Desiccation during these periods can lead to xylem cavitation and loss of hydraulic conductivity (14), stem dieback (4) and reduced RGP (20). Desiccating conditions affect species differently with regard to tissue (3) and growth stage vulnerability (9); survival, therefore is often species specific (8). Bates (1) reported Washington hawthorn shoots lost water more rapidly in cold storage than Norway maple shoots and that water loss through hawthorn stems negatively impacted root water potential. These results indicated that while root protection for all bare-root stock is imperative, desiccation sensitive species such as hawthorn require both shoot and root protection to minimize water stress during cold storage. There is little information available comparing the impact of water loss during cold storage on the RGP and bud break of desiccation sensitive and tolerant species. Therefore, the objective of this study was to determine the influence of root and shoot exposure to the atmosphere during storage and handling prior to transplanting, on RGP, timing of bud break and marketability of a desiccation tolerant (Norway maple) and desiccation sensitive (Washington hawthorn) species.

Materials and Methods

On January 14, 1993, 2-year-old Norway maple (*Acer platanoides* L.) and Washington hawthorn (*Crataegus phaenopyrum* Med.) bare-root seedlings with 60–90 cm (24–36 in) shoots were received in Blacksburg, VA, from Lawyer Nurseries, Plains, MT. Prior to shipping, trees were held in 2C ± 1C (35F ± 2F) and 98% ± 5% relative humidity cold storage for about 30 days at Lawyer Nurseries. Seedling bundles were wrapped in plastic sheeting and placed in card-

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board boxes with the roots of each bundle packed in moistened, shredded newsprint. Transit time was about five days. Trees were sorted for uniformity, and 240 seedlings of each species were randomized and placed on wooden racks in a walk-in cooler maintained at 70% ± 5% relative humidity and 2C ± 1C (35F ± 2F). At the time seedlings were placed into cold storage one of the following four treatments were randomly allocated to each tree: 1) whole plant covered, the entire seedling was enclosed in a sealed storage bag (Union Camp Corp., Tifton, GA), 2) shoot exposed, seedling roots were enclosed in a storage bag sealed around the stem just above the root collar, 3) roots exposed, shoots were enclosed in a storage bag sealed just below the root collar and 4) entire seedling exposed (no storage bag). Storage bags consisted of an external waxed paper layer covering an internal layer of polyethylene and were impermeable to water vapor. 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, 1993 (2, 4, 6, 8, 10, and 12 weeks in storage, respectively), 10 Washington hawthorn and 10 Norway maple trees from each treatment were randomly selected and removed from cold storage. All trees from each species × treatment combination were planted into 46 × 10 × 41 cm (18.4 × 4 × 16.4 in) trays containing 100% pine bark. The RGP test was conducted in a greenhouse where air temperatures were maintained at 24C ± 2C (75F ± 4F) day, 16C ± 2C (60F ± 4F) night and day length was extended to 16 hr with sodium vapor lamps. After 28 days, half the seedlings were carefully removed from the trays, the pine bark washed from the roots and the number of new white roots counted for each seedling (5). Days to first bud break and marketability were determined for the remaining 5 trees from each combination. Plants with less than 10% shoot dieback were considered marketable. Trees of each species and storage treatment were removed from cold storage at each cold storage duration and exposed to desiccating conditions prior to the RGP

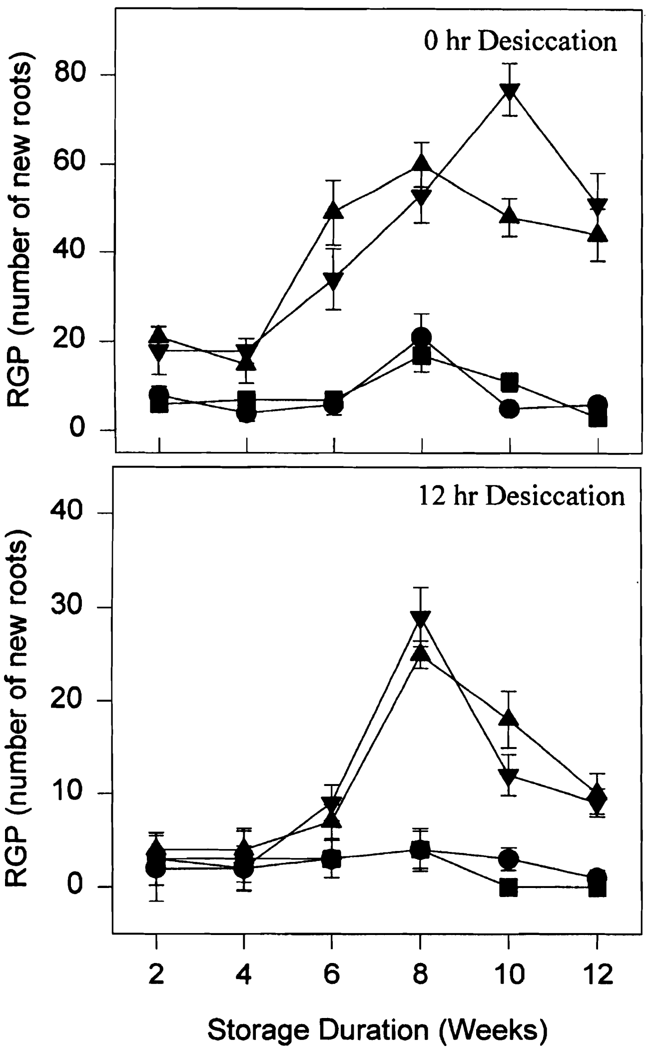

Fig. 1. Root growth potential (number of new roots per seedling 0.5 cm in length) of cold-stored 2-year-old Norway maple seedlings measured after 0 hr and 12 hr pre-transplant desiccation treatments. Storage treatments: whole plant covered (▼), shoots exposed (▲), roots exposed (■), whole plant exposed (●). Vertical bars represent ± S.E. of means, n = 5.

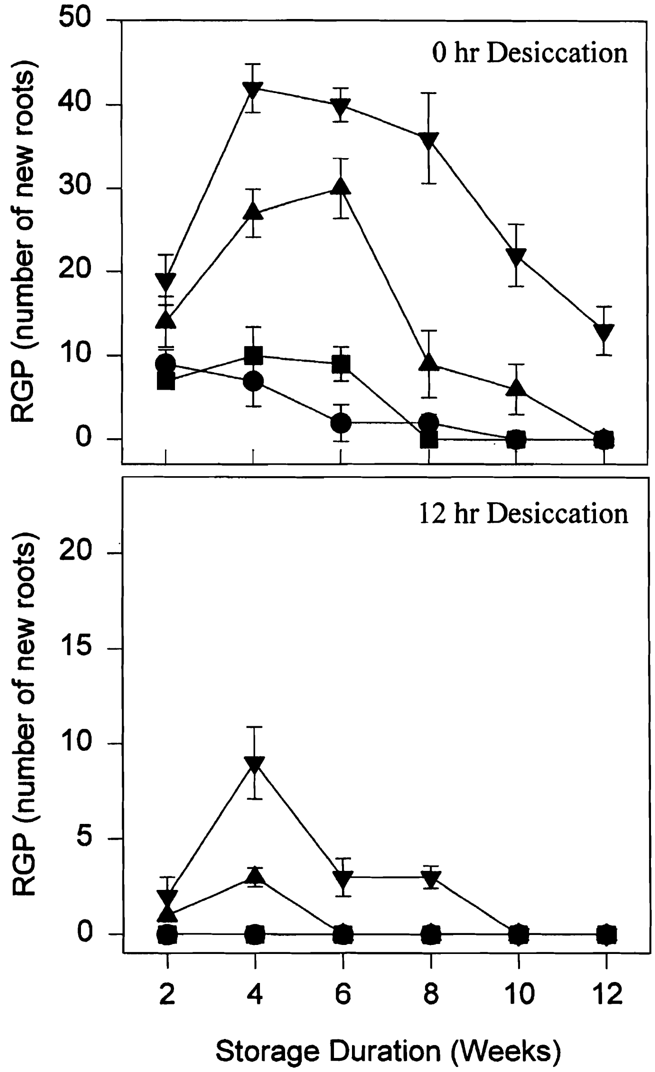

Fig. 2. Root growth potential (number of new roots per seedling 0.5 cm in length) of cold-stored 2-year-old Washington hawthorn seedlings measured after 0 hr and 12 hr pre-transplant desiccation treatments. Storage treatments: whole plant covered (▼), shoots exposed (▲), roots exposed (■), whole plant exposed (●). Vertical bars represent ± S.E. of means, n = 5.

Table 1. **Influence of cold storage duration and storage treatment on the number of days between transplanting and first bud break for 2-year-old Norway maple and Washington hawthorn.**

	Storage duration (weeks)					
	2	4	6	8	10	12
Storage treatment	**Days to first bud break**					
	Maple					
Whole plant covered	37a[zy]	35a	32a	31a	24a	20a
Shoots exposed	39a	36a	30a	27a	25a	27a
Roots exposed	36a	33a	36a	48b	45b	49b
Whole plant exposed	32a	36a	50b	49b	54b	57b
	Hawthorn					
Whole plant covered	29a[zy]	23a	20a	21a	17a	13
Shoots exposed	31a	30ab	42b	54b	62b	*
Roots exposed	33a	41b	39b	44b	*	*
Whole plant exposed	38a	37b	49b	*	58b	*

[z]Mean separation by Duncan's multiple range test, P = 0.05.

[y]Means in columns followed by the same letter are not significantly different.

Asterisk (*) indicates that plants had not broken bud 90 days after transplanting.

test. All seedlings receiving the desiccation treatment were placed on a lab bench and allowed to air-dry at 24C ± 2C (75F ± 4F) and 35% ± 5% relative humidity for 12 hr. Data were subjected to analysis of variance. A factorial set of treatments: 2 species, 4 cold storage treatments, 6 storage durations was replicated 5 times using a completely randomized design. Desiccation time (0 hr vs. 12 hr) data were analyzed separately.

Results and Discussion

Norway maple RGP (number of new roots per transplanted seedling) generally increased over time and was highest for treatments covering roots (whole plant covered and shoots exposed) compared to treatments without root covering (0 hr desiccation; Fig. 1). RGP for plants that had roots covered and received a 12 hr desiccation treatment increased until week 8 and decreased thereafter. RGP was near zero at each storage duration for treatments exposing roots (whole plant exposed and roots exposed). Hawthorn RGP (0 hr desiccation) was greatest for the whole plant covered treatment and increased from week 2 to 4 and decreased thereafter (Fig. 2). RGP for the shoot exposed treatment was intermediate between the whole plant covered treatment and the two treatments exposing roots for weeks 4 through 10. As with Norway maple, the 12 hr desiccation treatment reduced Washington hawthorn RGP for all treatments, with the whole plant covered treatment being higher for week 4 through 8 than the other covering treatments. There was an increase in RGP on week 4 for the root covered treatments, with RGP decreasing thereafter.

The increase in RGP over time for maple is in agreement with Webb (19) who reported increasing RGP with increased storage duration for *Fraxinus americana* L. seedlings. Also, entirely covered hawthorn plants had higher RGP than plants that only had roots covered, indicating that stem water loss influenced root regeneration. This finding coincides with water potential data reported by Bates et al. (2) where hawthorn plants that were completely covered had higher root water potentials than plants with only roots covered. This suggested that water lost through the stems negatively impacted root water relations. Apparently, the negative effect of storage duration on hawthorn root emergence is at least in part due to water stress acquired in storage. Commercial nurseries typically cover only the roots of bare-root trees during storage (Lawyer Nurseries, personal communication). Our results indicate that completely covering desiccation sensitive species such as Washington hawthorn during storage will improve new root initiation after transplanting. Reduced RGP of both species after a 12 hr desiccation treatment demonstrated the importance of protecting roots during the transplanting process.

Differences among storage covering treatments in the number of days required for maple seedlings to break bud were not evident until 6 weeks of cold storage (Table 1). At 8 weeks of storage and thereafter, the time to bud break for treatments exposing roots was greater than both treatments covering roots. After 4 weeks of storage, the time to hawthorn bud break was less when the whole plant was covered compared to other treatments (except shoots exposed) and the days to bud break decreased with storage time (Table 1). Also, with 12 weeks of storage, plants that were not totally covered did not show signs of bud break after 90 days and stems were visibly desiccated. In a study using green ash (*Fraxinus pennsylvanica* Marsh.) and paper birch (*Betula papyrifera* Marsh.), Harris et al. (7) reported that days to bud break decreased as cold storage duration increased and that trees heeled in with moist vermiculite experienced no stem dieback. Bud break data for the whole plant covered storage treatment (both species) of this study are in agreement with Harris et al. (7); however, as storage desiccation increased (roots exposed, whole plant exposed storage treatments) days to first bud break and stem dieback also increased.

Marketability for maples with roots covered (whole plant covered and shoots exposed storage treatments) was 100% beyond 6 weeks of cold storage (Table 2). For treatments exposing roots only, marketability was 40% or less at all storage durations. In contrast, hawthorn marketability for the whole plant covered treatment was 100% after 4 weeks of

Table 2. Influence of cold storage duration and storage treatment on the marketability of 2-year-old Norway maple and Washington hawthorn.

Storage treatment	Storage duration (weeks) 2	4	6	8	10	12
	Marketability (%)[z]					
	Maple					
Whole plant covered	40	40	100	100	100	100
Shoots exposed	20	100	100	100	100	100
Roots exposed	20	0	20	40	20	0
Whole plant exposed	0	20	0	40	0	0
	Hawthorn					
Whole plant covered	60	100	80	40	20	20
Shoots exposed	40	60	60	0	0	0
Roots exposed	0	0	0	0	0	0
Whole plant exposed	0	0	0	0	0	0

[z]Percent marketability: number of plants with ≤ 10% shoot dieback ÷ total number of plants (n = 5), evaluated after 90 days.

storage but declined to 20% by week 10 and was 0% for the roots exposed treatments for all storage durations (Table 2). Compared to the root exposed treatments, only covering the roots (shoots exposed) increased marketability for the first 6 weeks in storage. Exposing Norway maple seedlings to a 12 hr desiccation treatment prior to transplanting resulted in 0% marketability for all storage treatment × duration combinations except the whole plant covered treatment at weeks 8 and 10 (80% and 80%, respectively) and the shoots exposed treatment at weeks 6, 8, and 12 (60%, 40% and 20%, respectively). A 12 hr desiccation treatment rendered hawthorn seedlings unmarketable for all storage treatments and durations (data not shown).

A major objective in assessing forest seedling RGP is to predict field survival and performance. Similarly, nurserymen are interested in post-transplant survival and subsequent marketability. In this study, a high positive correlation existed between RGP and marketability for Norway maple (r = 0.86) and Washington hawthorn (r = 0.91). Webb (19) reported a strong correlation between RGP and field survival for *Acer saccharum* Marsh., *Acer saccharinum* L., and *Fraxinus americana* L. This work demonstrated that the impact of storage duration and plant part exposure during storage on seedling physiology was species specific. Maple root exposure and hawthorn root and shoot exposure during storage had a negative effect on RGP, time to bud break and marketability.

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