Desiccation Tolerance of Deciduous Plants During Postharvest Handling[1]

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Abstract

Nurserymen consider Washington hawthorn (*Crategus phaenopyrum* Med.) sensitive and Norway maple (*Acer platanoides* L.) tolerant to postharvest practices. The desiccation tolerance, cold hardiness and water potential at various growth stages were monitored on field-grown Washington hawthorn and Norway maple. There were no differences between these two species in the rate of water loss in the root, shoot or whole plants. Hawthorn, however, was more sensitive to desiccation stress than maple throughout all growth stages. The roots lost water at a faster rate than the stems in both species. Hawthorn plants acquired rest and cold hardened later in the fall and attained less dormancy and less freezing tolerance than did maple.

Index Words. Dormancy, rest, storage, transplant, water stress, water potential, freezing resistance, cold hardiness, Hawthorn, *Crataegus phaenopyrum* Med., Norway maple, *Acer platanoides* L.

Significance to the Nursery Industry

Sensitivity to desiccation stress during nursery handling is the main reason for poor regrowth of bare-rooted plants. Plants subjected to this stress during any phase of nursery production will have reduced growth potential and poor quality. From this study it appears that rest intensity, cold hardiness and desiccation resistance are related. Plants that are sensitive to desiccation stress may lack the ability to develop a high degree of rest. For these plant species, special care in the prevention of water stress during postharvest handling may be vital to their survival and growth potential at transplanting and establishment. Different protocols for harvesting and handling of these desiccation sensitive species need to be developed.

Introduction

Bare-root deciduous nursery stock is commonly stored at low temperatures. The storage potential of bare-root deciduous nursery plants differs dramatically among species (15) and genotypes within a species (11). Several members of the genus *Crataegus* of the Rosaceae family showed poor regrowth after postharvest handling (Warren, K., personal communication).

Poor regrowth of deciduous ornamentals after bare-root digging and storage can be attributed to improper handling procedures, inadequate nutritional status, lack of maturity at harvesting and desiccation stress (5, 7, 8, 12). Among these factors, desiccation stress imposed at harvesting, storage, transplanting, or establishment is thought to be one of the major causes of regrowth failure (6–8, 13–16).

Dormant plants are more tolerant of environmental stresses than the same plants during non-dormant stages (2, 3). Plants that are harvested during the dormant season of the year generally withstand postharvest handling and cold storage conditions better. This is probably because dormant plants are less susceptible to desiccation stress (4). Thus, the level of stress tolerance of dormant plants may correlate with the ability of bare-root deciduous ornamentals to withstand postharvest practices.

The objectives of this study were to determine desiccation tolerance, winter hardiness, dormancy status, and water potential of Washington hawthorn and Norway maple at various growth stages.

Materials and Methods

Two-year-old seedlings of Norway maple and Washington hawthorn were harvested from October 10, 1987 to April 14, 1988 from adjacent field plantings at the J. Frank Schmidt Nursery, Boring, OR. Immediately after lifting, ten plants from each species were randomly selected, the top 7.6 cm (3 in) stem of each plant was excised and xylem water potential was measured between 11:00 a.m. to 1:00 p.m. by a portable PMS Instrument Company pressure chamber.

The remaining plants were brought back to the laboratory, sized for uniformity, defoliated at the abscission zone, washed to remove soil and separated into three experimental groups. The first group was subjected to a desiccation test in which 10 whole plants and 10 sets of plant parts (whole plants, separated into roots at the shoot/root interface) were placed on a laboratory bench top at 22°C (72°F) and 43% relative humidity (RH). Cut surfaces of plant parts were dipped in 52°C (125°F) melted Paraplast paraffin to reduce water loss from cut surfaces. Water loss was measured by changes in fresh weight (hourly).

The second group consisting of 60 whole plants was placed on a laboratory bench at 22°C (72°F) and 43% RH. Xylem water potential was measured sequentially on 12 groups of 5 plants per group at 2 hour intervals with the pressure chamber. Immediately after measurement, the respective groups that had been exposed from 0 to 24 hours of drying conditions prior to measurement of water potentials were transplanted into 25.4 cm (10 in) pots, containing a medium composed of sandy loam, pumice and peat moss (2:1:1 v/v/v), and placed in a greenhouse at 22°C (72°F) day 15° (59°F) night temperatures and a 16 hour photoperiod (LD).

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Natural daylength was extended with sodium vapor lights from 1400 to 2400. The light intensity at plant height measured at 1200 and 1800 was approximately 100 $\mu E\ m^{-2}s^{-1}$ (475 fc) and 150 $\mu E\ m^{-2}s^{-1}$ (713fc), respectively. The total number of bud breaks was determined 21 days after transplanting. The critical xylem water potential was defined as the water potential causing a 50% reduction in the number of bud breaks over the 21 day treatment period.

The third group of plants was utilized for the determination of freezing resistance of stem tissue and dormancy status. Freezing resistance was determined utilizing 3.8 cm (1.5 in) internodal stem tissue taken below the third node of the main leader. Five stem sections per replicate, with 3 replicates, from each plant species were placed in a moistened filter paper-lined 9.5 cm (3.8 in) plastic petri dish with cover. Freezing tests were conducted in a Cryomed Model 990C liquid nitrogen programmable freezer. Samples were equilibrated at 0°C (32°F) for 30 minutes. Ice nucleation was initiated at −2°C (28.4°F) by rapidly dropping the chamber temperature to −30°C (−22°F) for about 1 min. Water vapor condensed on the inside of the petri dish froze, initiating freezing of the moistened filter paper, while the tissue temperature was maintained above −3°C. The temperature was reduced at the rate of 3°C/hour until a final temperature of −40°C (−40°F) was attained. Samples were removed at 3°C intervals, thawed at 0°C for 24 hours, and incubated in the moistened petri dish for 5 days at room temperature in the dark. Tissue viability was determined by visual browning of the stem tissues. LT50 is defined as the temperature at which 50% of the stems were dead.

The dormancy status of the plants was determined by time required to break bud under the LD conditions described previously. Ten plants taken from the field monthly were planted in 25.4 cm (10 in) pots containing a medium of sandy loam, pumice and peat moss (2:1:1 v/v/v).

Statistical Analysis. With the exception of the cold-hardiness determination, data were subjected to analysis of variance procedures through the use of SAS. Waller/Duncan procedure was utilized for mean separation of treatments at the 5% level. Each species was analyzed separately in a split-plot arrangement with time as the main block.

Results and Discussion

Field-grown hawthorn and maple plants were collected at different times during the winter season and evaluated for rest status by determining the number of days to bud break. This study revealed that rest occurred in both plant species with maple acquiring rest earlier and maintaining rest longer than hawthorn (Fig. 1). Deepest rest occurred in December for Washington hawthorn and January for Norway maple. At deep rest, Norway maple required 25 days to break buds whereas Washington hawthorn required only 15 days. The termination of rest in hawthorn and maple occurred by the end of January and end of February, resp.

Plants transplanted and watered immediately from the field in December, when both plants were at rest, had high percentages of bud break after 21 days regrowth in the greenhouse (Table 1). After a short desiccation period (12 hrs), survival rates declined in both species, with the greatest loss of bud break occurring in hawthorn. After 24 hours of desiccation, none of the hawthorn plants grew, whereas 54% of the Maple grew.

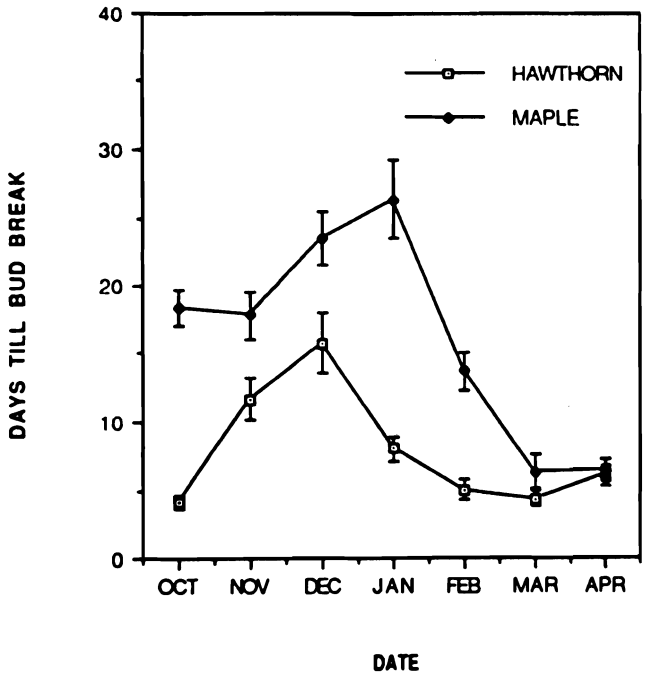

Fig. 1. Comparison of rest status between Washington hawthorn and Norway maple plants grown in the field, harvested at different dates, and subjected to a 16 h. photoperiod at 22°C (72°F) day and 15°C (59°F) night condition.

Under natural field conditions, the water status of hawthorn and maple plants was different (Fig. 2). The water potential of hawthorn plants decreased in December, reached its lowest level of −1.1 MPa (−11 bar) in January and then gradually increased to the October level by March (Figure 2). In contrast, the water potential of maple plants began declining in November, reached its lowest potential in January, and gradually increased to the October level in March.

A comparison of water loss between plant species in December found little difference in the rate of water loss between species (Figure 3). The roots lost water at a faster rate than the shoots in both species (Fig. 4). The pattern of water loss of the roots and shoots of both species was similar.

Comparison of the critical water potential between hawthorn and maple indicates that maple was more desiccation tolerant than hawthorn in all but the February sample period

Table 1. Influence of water stress on regrowth of Washington Hawthorn and Norway Maple in December.

Treatment	Water Potential (MPa)	Bud Break[y] (%)
Hawthorn		
immediately from field	−0.8 a[z]	78% a
12 hours drying	−2.5 b	27% b
24 hours drying	−3.6 c	0% c
Maple		
immediately from field	−1.5 a	100% a
12 hours drying	−1.9 b	78% b
24 hours drying	−2.9 c	54% c

[z]Mean separation within columns by Waller/Duncan test, 5% level.
[y]% bud break 21 days after transplanting.

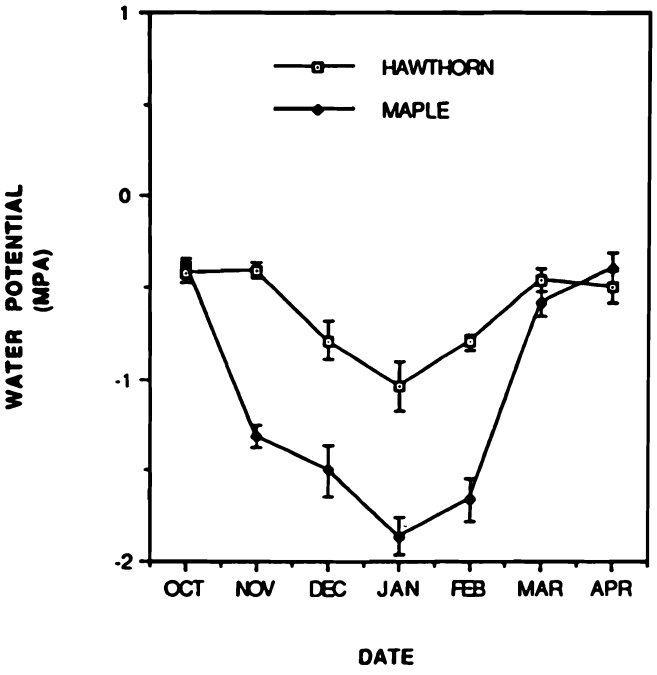

Fig. 2. Changes in water potential of field-grown Washington hawthorn and Norway maple plants at different sampling dates.

(Table 2). The desiccation tolerance of hawthorn did not change substantially during the sampling period. In December only, a slight, but significant, increase in desiccation tolerance occurred. In contrast, maple was quite desiccation tolerant from October to January.

Maple was hardier and cold acclimated well in advance of hawthorn. By October, maple plants were able to survive to −24°C (−11.2°F), while hawthorn plants survived to only −4°C (24.8°F). Hawthorn did not exhibit a significant degree of hardiness until December. Maximum hardiness (LT50) for hawthorn and maple plants occurred in January and December, resp. (Table 2).

Webb and von Althen (15) demonstrated that moisture loss by broadleaf trees during cold storage adversely affected their root growth capacity and, subsequently, the survival and vigor of the transplanted plants. Insley and Buckley (6)

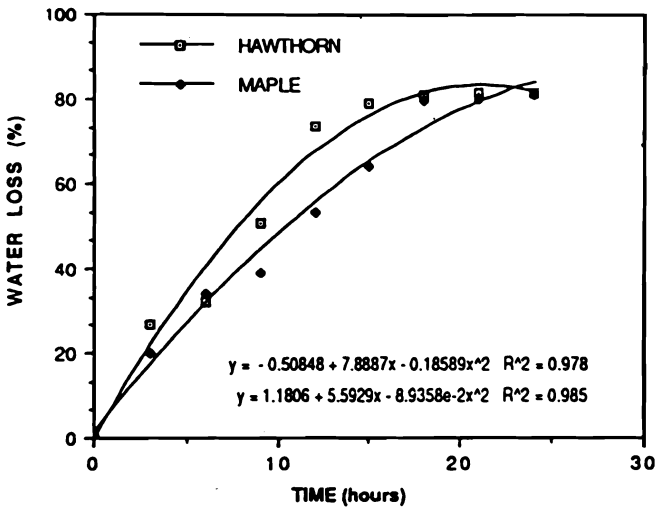

Fig. 3. Water loss from Norway maple and Washington hawthorn plants (roots and shoots combined), in December.

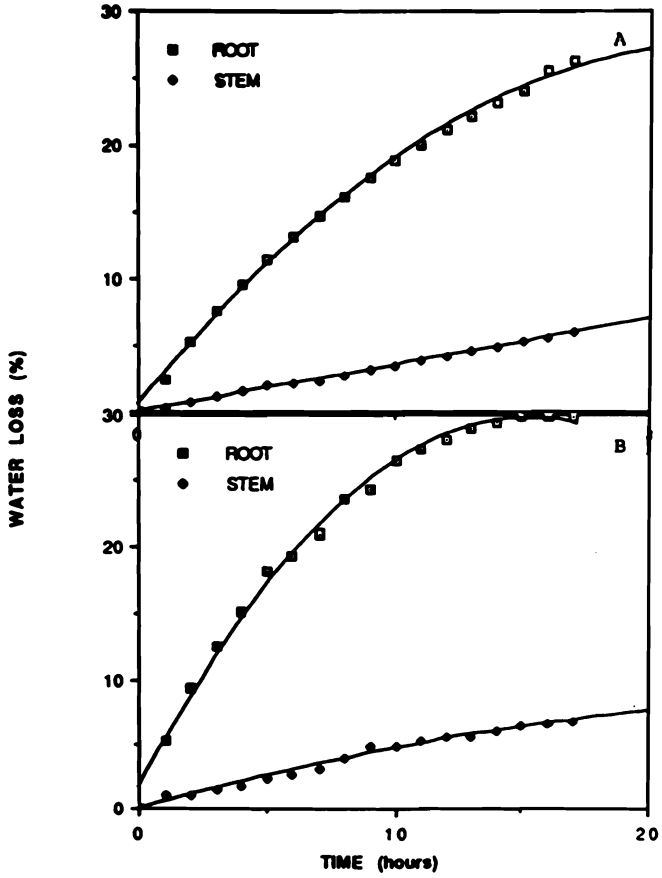

Fig. 4. Water loss from Washington hawthorn (A) and Norway maple (B) from separated roots and stems, in December.

reported that bare-root *Fraxinus angustifolia* and *Betula pubescens* seedlings dried out rapidly. *Fraxinus* seedlings were more tolerant to desiccation than *Betula* seedlings. They found that 12 hours of drying at 20°C (68°F) and 50% RH in *Fraxinus* seedlings had no significant effects on the survival, whereas the same treatment caused more than 40% reduction on the survival of *Betula*. Our findings on Norway maple and Washington hawthorn were similar and support their findings that species differ in desiccation tolerance.

In spite of the dramatic difference in desiccation tolerance between Norway maple and Washington hawthorn plants, the rate of water loss from either whole plants (Fig. 3) or root and stem tissues (Fig. 4) was similar. These results indicate that Norway maple plants do not possess any morphological advantages over Washington hawthorn plants to prevent the stem and root tissues from drying. Thus, the difference in the sensitivity to desiccation between maple and hawthorn seems to reside at the cellular level.

Generally, plants that are more tolerant of desiccation stress are also more tolerant of freezing stress. This is not surprising since one of the current hypothesis of freezing injury is the loss of protoplasmic water due to extracellular freezing (1, 9). By comparing the fraction of unfrozen water between *Solanum* species, Chen, et. al. (1) concluded that the hardy species were able to tolerate more desiccation due to extracellular freezing than the less hardy species. The present study is in agreement with these findings. Norway maple plants were found to be considerably more cold and desiccation tolerant than hawthorn plants (Table 1).

Table 2. Changes in cold hardiness and critical water potential of Washington Hawthorn and Norway Maple seedling.

Date	LT50 (°C)		Critical Water Potential[x] (MPa)	
	Hawthorn	Maple	Hawthorn	Maple
OCT	−4 ± 2.1	> −24	−1.7 b[y]	−2.2 b
NOV	−7 ± 2.1	> −34	−1.6 b	−3.2 a
DEC	−22 ± 2.1	> −40	−2.1 a	−3.2 a
JAN	−28 ± 2.1	> −40	−1.5 b	−2.4 b
FEB	−22 ± 2.1	—[z]	−1.7 b	−1.8 c

[z]Data not available.

[y]Mean separation within columns by Waller/Duncan test, 5% level.

[x]Critical water potential is defined as the water potential that causes a 50% reduction in bud break.

Another explanation for the large difference in desiccation tolerance between hawthorn and maple plants may be due to the inability of hawthorn plants to develop a high degree of rest (Fig. 1). Hawthorn plants failed to acquire rest under growth chamber conditions (Murakami, unpublished data) and achieved a lower degree of rest under natural conditions between November and January (Fig. 1).

Our studies confirm previous findings that resting plants are generally more tolerant of desiccation stress (2, 3). For many plant species, lifting at rest would be advantageous in that the risks of postharvest handling failure would be reduced (14, 15).

Currently, there are no quick methods for the accurate diagnosis of the dormancy status of plants. Tests for measuring rest in plants require several days and sometimes weeks to evaluate their growth status. Our results (Fig. 1 and 2) indicate a high negative correlation between midday water potential (−MPa) and dormancy status (days to bud break) ($R^2 = 0.673$, $P \leq 0.05$). These studies suggest water potential measurement may be a possible indicator of rest status. Earlier work supporting these findings include the strong association between growth stage and pre-dawn water potential (5) and high correlation between water potential and development of cold hardiness. Nevertheless, before water potential can be used as a measure of the dormancy status of plants, further tests are necessary.

Literature Cited

1. Chen, P.M., Burke, M.J. and Li, P.H. 1976. The frost hardiness of several *Solanum* species in relation to the freezing of water, melting point depression, and tissue water content. Bot. Gaz. 137:313–317.

2. Fuchigami, L.H. 1977. Ethephon-induced defoliation and delay of spring growth in *Cornus stolonifera* Michx. J. Amer. Soc. Hort. Soc. 102:452–454.

3. Fuchigami, L.H., C.J. Weiser, K. Kobayashi, R. Timmis, and L.V. Gusta. 1982. A degree growth stage (°GS) model and cold acclimation in temperate woody plants. p. 93–116. In: Li, P.H. and A. Sakai (Eds.), Plant Cold Hardiness and Freezing Stress. Volume 2. Academic Press, New York.

4. Garber, M.P. and J.G. Mexal. 1980. Lift and storage practices: Their impact on successful establishment of southern pine plantations. New Zealand J. For. Sci. 10:72–82.

5. Hotze, M.L. 1976. Indicators of deciduous shade tree development useful for timing chemical defoliants and harvest. Ph.D. thesis. Oregon State Univ., Corvallis, OR.

6. Insley, H. and G.P. Buckley. 1985. The influence of desiccation and root pruning on the survival and growth of broad-leaf seedlings. J. Hort. Sci. 60:377–387.

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

8. Lee, C.I. and W.P. Hackett. 1976. Root regeneration of transplanted *Pistachia chinensis* Bunge. seedlings at different growth stages. J. Amer. Soc. Hort. Sci. 101:236–240.

9. Levitt, J. 1980. Responses of plants to environmental stresses. Vol. 1. 2nd Ed. Academic Press, New York.

10. Parmelee, K. 1979. The relationship of electrical impedance to vegetative maturity and dormancy in red-osier dogwood. M.S. thesis. Oregon State University, Corvallis, OR.

11. Rebhuhn, M.K. 1985. Characterization of harvestable maturity development in roses. M.S. thesis. Oregon State University, Corvallis, OR.

12. Stone, E.C. and G.H. Schubert. 1959. Root regeneration by Ponderosa pine seedlings lifted at different times of the year. For. Sci. 5:322–332.

13. Wargo, P.M. 1983. Effects and consequences of stress on root physiology. J. Arboriculture 9:173–176.

14. Webb, D.P. 1976. Effects of cold storage duration on bud dormancy and root regeneration of white ash (*Fraxinus americana* L.) seedlings. HortScience 11:155–157.

15. 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. 10:83–86.

16. Zahner, R. 1968. Water deficits and growth of trees. p. 199–254. In: Kozlowski, T.T. (Ed.), Water Deficits and Plant Growth. Volume 2. Academic Press, New York.