Drying and Rehydration of Atlantic White Cedar, Arizona Cypress, Eastern White Pine, Leyland Cypress, and Virginia Pine Christmas Trees

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Abstract. Drying and rehydration characteristics were measured for Atlantic white cedar [*Chamaecyparis thyoides* (L.) B.S.P.], Arizona cypress [*Cupressus arizonica* var. *glabra* 'Carolina Sapphire' (Sudworth) Little], Leyland cypress [*Cupressocyparis leylandii* (A. B. Jacks. & Dallim.)], Virginia pine (*Pinus virginiana* L.), and eastern white pine (*Pinus strobus* L.) Christmas trees. Species varied in drying rate, loss of mass during display, water use after rehydration, the relationship between moisture content and xylem water potential (Ψ), and keeping quality. Leyland cypress and Arizona cypress rehydrated from Ψ values as low as -5.0 MPa, and remained in good condition after rehydration. The critical moisture content for Virginia pine and white pine was between -2.5 and -3.0 MPa. The ability of Atlantic white cedar to rehydrate decreased quickly with time out of water, and water consumption dropped sharply within a few days after placement in water. Change in fresh mass varied from $+1\%$ for Arizona cypress to -29% for Atlantic white cedar. Keeping quality of Virginia pine was poor, even for trees that were placed in water the day of cutting.

Conifers used as cut Christmas trees vary in their rate of drying following harvest, and their ability to maintain freshness during display. For example, Fraser fir [*Abies fraseri* (Pursh) Poir.] dries slowly, and is durable in the postharvest environment, whereas eastern red cedar (*Juniperus virginiana* L.) dries rapidly, and has a limited shelf life, even when standing in water (Hinesley, 1984, 1988). The critical moisture content (CMC) is the moisture level at which a tree fails to completely rehydrate when returned to water (Van Wagner, 1963), or, despite significant water uptake, deteriorates in quality. Symptoms include light green foliage, needle abscission, discoloration, and/or brittleness of foliage and twigs (Chastagner, 1986; Montano and Proebsting, 1986). Published values of CMC, as determined with a pressure bomb (PMS Instruments, Corvallis, Ore.), for various Christmas tree species range from -3.0 to -4.5 MPa

(Hinesley, 1984, 1988; Hinesley and Snelling, 1995; Montano and Proebsting, 1986; Seiler et al., 1988). Our objective was to compare postharvest drying, rehydration, and keeping quality of the following five species grown as Christmas trees in the Piedmont and Coastal Plain of the southeastern United States: Atlantic white cedar (AWC), Arizona cypress 'Carolina Sapphire' (CS), Leyland cypress (LC), Virginia pine (VP), and eastern white pine (WP).

Materials and Methods

Three species (CS, LC, and VP; 2 to 3 m tall) were taken from a Christmas tree farm near Sanford, N.C. (Lee Co.); AWC and WP

Christmas trees of similar size came from a Christmas tree farm near Raleigh (Wake Co.). There were 15 trees of CS, LC, VP, and WP, but only five of AWC were utilized, owing to limitations in space.

Trees were harvested on 6 Dec. 1995. Those from Wake Co. (except for one AWC that was harvested on 15 Dec.) were cut early in the morning, weighed, transported ≈ 8 km to a university research lab, and stored temporarily in an unheated receiving room. Those from Lee Co. were harvested between 1030 and 1230 HR. During harvest, temperatures ranged from 6 to 14 °C, and the sky was overcast most of the morning. Before harvest, water potential (Ψ) was measured on two trees of each species, using a pressure bomb. Shoots were stored on ice for moisture content determination, as described later. Trees were weighed, baled, loaded in covered trucks, and transported ≈ 80 km to Raleigh.

The study was carried out in an adjacent room (14 × 7 m, concrete floor, fluorescent lighting, gas heat). Temperature was ≈ 23 °C, with relative humidity of 50% to 80%. Three control trees (day = 0) of each type (one tree for AWC) were recut (a 2- to 3-cm section was removed from the base of the trunk), and stood in buckets containing water. Remaining trees were secured upright against rigid frames, and placed in water after designated intervals of time. Trees were distributed in the room, using a randomized complete-block design with three replications.

Drying intervals (Table 1) varied because we were uncertain what intervals to use for each species. Trunks of three trees of each species (except AWC) were placed in water after each drying interval. Only one AWC was sampled for each drying interval (0, 2, 4, 5, and 8 d).

Ψ was measured periodically with a pressure bomb to establish the drying and rehydration curve for each species. One shoot 6–10 cm long was used for each measurement. After measurement of Ψ , each shoot was weighed, dried to constant mass at 65 °C, and weighed again. Percent moisture content (MC) was calculated as [(fresh mass – dry mass)/dry mass] × 100%.

Table 1. Effect of drying time on final quality rating of Arizona cypress (CS), Leyland cypress (LC), eastern white pine (WP), Virginia pine (VP), and Atlantic white cedar (AWC) Christmas trees following rehydration.

Drying time (days) ^a	Rehydration time (days)	Species				
		CS	LC	WP	VP	AWC ^c
0	27	G ^a	G	G	P	G
2	25	G	G	G	P	G
4	23	G	---	---	---	G
5	22	---	---	---	P	G
6	21	G	G	---	---	---
8	19	---	---	---	---	---
11	16	---	G	---	---	---
13	14	---	---	G	D	---
15	12	---	G	---	---	---
17	10	---	---	F	D	---
20	7	---	---	F	---	---

^aRatings were conducted after 27 d. Temp = 23 °C, relative humidity = 50% to 80%.

^bData were omitted for AWC (day 8) because that tree was cut on a later date than the other species.

^cG = good, F = fair, P = poor, D = dead. Ratings for AWC, LC, CS, and WP are based on three trees; for AWC, one tree per treatment.

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Water consumption was measured periodically by filling each container to a fixed reference point. Two 'blank' buckets were placed in the room to measure evaporation. Water use was expressed as $\text{L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ of initial fresh mass. Fresh mass varied from 3 to 8 kg.

The experiment ended on 3 Jan. 1996. Each tree was subjectively rated for quality, based on needle retention, foliage color, fragrance, and twig pliability. Final fresh mass was recorded for each tree. Results are presented graphically.

Results and Discussion

Species differed in drying rate, water use, loss of mass, and keeping quality. CS dried most rapidly, reaching -5 MPa in 6 d (Fig. 1A), followed closely by AWC, which reached -5 MPa in 8 d. LC dried to -4 MPa in 7 d, followed by slower drying to -5 MPa by day 15. Pines exhibited a different drying pattern. Ψ of WP reached -2.2 MPa by the second day, then declined by only -0.4 MPa during the following 18 d (Fig. 1A). Similarly, VP reached -2.0 MPa after 1 d, decreased to -2.9 MPa by day 4, and did not exceed -3.1 MPa thereafter.

Xylem Ψ is a good indicator of moisture content when trees are in the drying phase (period between cutting and the time of return to water). For AWC and CS, the relationship was linear over a wide range in Ψ (-0.95 to -5.1 MPa), and measurements were consistent (Fig. 1B). The relationship was less clear for VP and WP, where Ψ quickly reached -2.0 to -2.2 MPa in the first 2 d and changed very slowly thereafter. At that point, the narrow range in Ψ and the slow change in Ψ with passing time (Fig. 1A) would make Ψ less reliable for predicting moisture status of VP and WP. Larger sample size might increase precision and accuracy for species that display this drying pattern.

Species varied with respect to water use (Fig. 1C). AWC returned to water on day 2 used $\approx 0.20 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$. With additional drying, water use decreased sharply; e.g., the tree placed in water on day 8 ($\Psi = -5.0$ MPa) used only $0.03 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ during 10 d of display. WP transpired $\approx 0.11 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ for trees dried 0 or 3 d, and decreased gradually to $\approx 0.08 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ for trees dried up to 20 d. Maximum water consumption for VP was $\approx 0.07 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$, and gradually decreased for drying periods ≥ 2 d. Water consumption by LC was initially $\approx 0.17 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$, decreasing to $0.12 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ for trees dried 5 d (Fig. 1C). To our surprise, LC trees that dried for 11 d or 15 d transpired 0.22 and $0.28 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$, respectively. CS initially used $\approx 0.15 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$, and this changed little, even when trees were dried to -5 MPa before rehydration (Fig. 1C). In comparison, eastern red cedar, which dries rapidly, used $0.16 \text{ L} \cdot \text{day}^{-1} \cdot \text{kg}^{-1}$ over 14 d at 20°C in an earlier experiment (Hinesley, 1988).

When placed in water, a fresh tree commonly increases in mass (Davis and Fretz, 1972; Hinesley, 1984; Van Wagner, 1963). However, if water uptake decreases over time,

fresh mass can also decrease. CS was the only tree that maintained its original mass throughout the experiment (gain = 1%) (Fig. 1D). LC also endured well, losing only 3% to 6%, even when out of water 15 d ($\Psi = -5$ MPa). WP placed in water on day 0 decreased $\approx 7\%$ in mass during the 27-d experiment; for the remaining drying treatments, loss in mass was 2% to 13%.

VP and AWC lost the most mass on a percentage basis (Fig. 1D). For VP, the loss ranged from 13% (day 0) to 21% (trees dried 17 d; $\Psi \approx -3.0$ MPa). The AWC tree that was placed in water on day 0 lost 15% of its initial fresh mass; the mass of the tree dried 5 d decreased by 29%.

After a tree rehydrated, Ψ could not be used as the sole determinant of tree quality. CS rehydrated well, and maintained Ψ values closest to the initial value over time (Fig. 2A). LC (Fig. 2B) and WP (Fig. 2C) showed small increases in Ψ over time, compared to initial values. All three species kept well during display. In contrast, WP (Fig. 2C) and VP (Fig. 2D) had similar patterns of drying and rehydration, but keeping quality was good for WP, poor for VP. AWC showed the most rapid loss in capacity to rehydrate, and the greatest tendency to dry while standing in water (Fig. 2E). These results were confirmed by measurements of water use and loss of mass (Figs. 1C and D). However, the appearance of AWC at

the end of the experiment (Table 1) was better than that of VP, which had less negative values of Ψ than AWC (Figs. 2D and E).

At the end of the experiment (27 d), CS and LC in all treatments were in good condition (Table 1), with good color and negligible needle loss. WP dried ≤ 13 d were in good condition, but some of those dried 17 and 20 d ($\Psi \leq -2.7$ MPa) were fading in color and/or losing needles on isolated twigs by day 27. All VP, including those placed in water the first day, were in poor condition at the end of the experiment; many appeared to be dead or dying. AWC dried ≤ 5 d appeared to be in good condition at the end of the experiment.

In the present study, CS dried rapidly, but showed no reduction in water consumption, fresh mass, quality, or rehydration, even when trees were dried to -5.0 MPa (Figs. 1, 2A). LC dried more slowly than CS, and also withstood drying up to -5.0 MPa (Table 1; Figs. 1A, 2B). The critical moisture content was between -2.5 MPa and -3.0 MPa for WP and VP (Figs. 2C and D); and between -3.5 MPa and -5.0 MPa for AWC (Fig. 2E).

The postharvest period has two phases: 1) the time before a cut tree is returned to water, and 2) the time after placement in water. With respect to (1), WP and LC were best, VP and AWC worst. With respect to (2), LC and CS were best, whereas VP and AWC were worst. Postharvest keeping quality of WP was far

Fig. 1. Effect of drying time (temp. = 23°C ; relative humidity = 50% to 80%) on Christmas trees. (A) Xylem water potential (Ψ) in relation to drying time; (B) relationship between Ψ and moisture content (dry mass basis) of small shoots; (C) water use (time interval: date when trees were returned to water until the end of the experiment); and (D) percent loss in mass during the experiment. Legend: (Δ) Atlantic white cedar, AWC; ($\circ$) Arizona cypress 'Carolina Sapphire', CS; ($\bullet$) Leyland cypress, LC; ($\diamond$) Virginia pine, VP; and (∇) eastern white pine, WP. Each data point is based on three trees for CS, LC, VP, and WP, and one tree for AWC.

Fig. 2. Drying and rehydration patterns for (A) Arizona cypress 'Carolina Sapphire', (B) Leyland cypress, (C) eastern white pine, (D) Virginia pine, and (E) Atlantic white cedar Christmas trees. Filled symbols are for trees without water. Numbers in parentheses indicate the days when trees were recut and placed in water. Each data point is based on three trees for CS, LC, VP, and WP; one tree for AWC.

superior to that of VP. In comparison, Fraser fir dries at rates comparable to WP (Hinesley and Snelling, 1991), and has a relatively long shelf life in water (Hinesley, 1984; Hinesley and Snelling, 1995). At the other extreme, eastern red cedar dries very rapidly and has a limited shelf life in water (Hinesley, 1988; Hinesley and Snelling, 1995).

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