in 1 and 5C storage, the accumulation of CO₂ and depletion of O₂ were determined as a percentage of total headspace gas (Figs. 1 and 2). The effects of reduced O₂ and elevated CO₂ on respiration are additive and can be greater than the effects of either alone (Zagory and Kader, 1988). Carbon dioxide accumulation averaged $\approx 24\%$ higher for the four films at 5C than at 1C. In films 1 and 2, those with higher gas transmission rates, gas composition was approaching equilibrium after 7 days of storage at both temperatures. Equilibrium was beginning to be reached in film 3 in ≈ 14 days; however, it was not reached in film 4 even then, i.e., CO₂ levels continued to increase during storage at both temperatures.

Oxygen levels in film 1, the one with the highest gas transmission rate, were generally higher than in the rest throughout storage at both temperatures. Oxygen levels ranged between 1% and 4% in films 2, 3, and 4 after 7 days of storage at either temperature (Fig. 2).

Our results indicate that film gas transmission rate and storage temperature are important in extending the shelf life of chopped lettuce, agreeing with those of others (Bolin et al., 1977; Krahn, 1977). Chopped lettuce stored at 5C had a significantly shorter shelf life, determined by appearance and flavor evaluations, than lettuce held at 1C. Although discoloration occurred and fermentation odors could be detected by the sensory panel when CO₂ levels rose above 20% (films 3 and 4), no discoloration or fermentation was reported when CO₂ was < 20% (films 1 and 2). Besides the discoloration of lettuce noticed in film 4 after 14 days, browning and discoloration of lettuce was seen in all bags when there was air leakage due to poor seals. Elevated O₂ levels in these latter packages presumably accounted for the browning and discoloration. We conclude that films with O₂ transmission rates > 3000 ml·m⁻²·day⁻¹·atm⁻¹ at 22C are required to extend the shelf life of 'Salinas' chopped lettuce when held at 1 to 5C.

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Latex Colorant Slows Drying of Redcedar Christmas Trees

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Abstract. Harvested eastern redcedar (*Juniperus virginiana* L.) Christmas trees coated with combinations of latex-based green colorant and needle sticker were observed for 2 weeks at 20C. Green colorant reduced drying rates and helped maintain a better water status following dehydration. Even though these materials improve postharvest water relations, their primary value with respect to marketing and use of eastern redcedar Christmas trees is to impart a better color and/or mask the prickliness of juvenile foliage.

In recent years, latex-based green colorants have been used extensively by Christmas tree producers to enhance tree appearance during the fall harvest season. Many Christmas tree species, particularly pines, become yellow-green in late fall. Colorants, similar to thin latex paint, prevent or mask this effect if applied before the change. Despite the positive effect on tree appearance, the notion that colorants and needle stickers prolong shelf life of cut Christmas trees has not been well tested. Recent work with Douglas-fir [*Pseudotsuga mensiesii* (Mirb.) France] indicated that antitranspirants and colorants, when used under moderate to strong drying conditions, did little to retard drying unless applied at levels sufficiently high to render the tree qualitatively less acceptable to consumers (Montano and Proebsting, 1986).

Eastern redcedar is indigenous to most of the eastern United States and is important as a Christmas tree, particularly at the local level and in choose-and-cut operations. It is naturally light green to purplish-green in late fall. Colorants are routinely used to make trees dark green. A disadvantage of redcedar is that it dries very rapidly following cutting (Hinesley, 1988). The effect of colorant and needle sticker on the drying rate of redcedar is unknown. Thus, the objective of the current work was to examine several of these products in relation to postharvest drying and

keeping quality of redcedar.

Eastern redcedar Christmas trees 1.5 to 2.0 m in height were used. Trees were growing ≈ 20 km southeast of Raleigh, N.C. Two products were tested (singly or in combination): 1) a representative latex-based, water-soluble pigment, Virginia Pinegreen, and 2) a liquid hydrostatic sticker, Needlehold (both, Kirk Co., Wautoma, Wis.). Table 1 lists the six treatments, which are similar to those that might be encountered in commercial Christmas tree operations. Each solution contained 3 ml Triton AG-98 spreader activator/liter (Rohm and Haas, Philadelphia, Pa.) and pH was adjusted to ≈ 8.2 with household ammonia (1 ml·liter⁻¹). The ammonia was included because experience suggested that it improved the uniformity of surface coverage by Virginia Pinegreen. Materials were applied to standing trees between 1:00 PM and 3:00 PM on 11 Dec. 1987, using a backpack sprayer [pressure = 0.2 to 0.3 MPa (30 to 40 psi); nozzle = 8003 LP flat spray tip (Spraying Systems, Wheaton, Ill.)]. Each tree received ≈ 0.6 liter of solution, which was enough to thoroughly wet visible portions of the crown. Ambient temperature was 13C; relative humidity 60%.

The 36 trees were harvested between 9:00 AM and 11:00 AM on 15 Dec. 1987. Temperature was 10C, accompanied by fine mist and fog. Initial xylem water potential (ψ) was measured with a pressure chamber (PMS Instruments, Corvallis, Ore.) and averaged -0.3 to -0.4 MPa (n = eight trees).

Trees were transported to Raleigh in a closed truck and stood upright in a 20C classroom. The room had fluorescent lighting between 8:00 AM and 10:00 PM daily. Relative humidity, which could not be controlled precisely, ranged from 30% to 70% during the 12-day experiment. When the water potential for an individual tree fell below -5.0 MPa (2 to 3 days), a 5-cm-thick disk

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Table 1. Drying rate of cut eastern redcedar following application of green colorant and needle sticker.

Treatment ^a	Hours after harvest (1987)			Hours to reach -5.0 MPa (1987)	Hours to reach -4.0 MPa (1988)
	0	24	48		
	ψ (-MPa)				
Control (none)	0.36 a ^y	3.4 c	5.5 c	43 a	35 a
Pinegreen (1:20)	0.36 a	2.2 a	3.5 a	70 b	52 b
Pinegreen (1:20), two coats	0.36 a	2.1 a	3.6 a	68 b	50 b
Pinegreen (1:20) + Needlehold (1:20)	0.36 a	2.3 a	3.9 a	67 b	53 b
Pinegreen (1:20) + Needlehold (1:4)	0.36 a	3.3 c	4.9 b	51 a	44 ab
Pinegreen (1:20), followed by Needlehold (1:4)	0.36 a	2.6 b	3.8 a	66 b	56 b

Pinegreen is Virginia Pinegreen and Needlehold is a sticker, both manufactured by Kirk Co., Wautoma, Wisc.

^yn = 6. Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range test.

Table 2. Xylem water potential of eastern redcedar Christmas trees 1, 6, and 12 days after placement of the basal stem in water (Expt. 1, 1987).

Treatment ^a	Day		
	1	6	12
	ψ (-MPa)		
Control (none)	0.79 b ^y	0.96 c	1.99 c
Pinegreen (1:20)	0.58 a	0.42 a	0.53 a
Pinegreen (1:20), two coats	0.58 a	0.52 ab	0.57 a
Pinegreen (1:20) + Needlehold (1:20)	0.53 a	0.48 a	0.51 a
Pinegreen (1:20) + Needlehold (1:4)	0.52 a	0.75 bc	1.38 b
Pinegreen (1:20), followed by Needlehold (1:4)	0.46 a	0.40 a	0.50 a

Pinegreen is Virginia Pinegreen and Needlehold is a sticker, both manufactured by Kirk Co., Wautoma, Wisc.

^yn = 6. Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range test.

Table 3. Water consumption and needle loss over a 12-day display period for eastern redcedar Christmas trees sprayed with green colorant and needle sticker (Expt. 1, 1987).

Treatment ^a	Water use (liters·kg ⁻¹)	Needle loss (g·kg ⁻¹)
Control (none)	1.49 bc ^y	0.92 a
Pinegreen (1:20)	1.22 a	0.91 a
Pinegreen (1:20), two coats	1.24 a	0.76 a
Pinegreen (1:20) + Needlehold (1:20)	1.34 ab	0.82 a
Pinegreen (1:20) + Needlehold (1:4)	1.60 c	0.39 a
Pinegreen (1:20), followed by Needlehold (1:4)	1.40 abc	1.11 a

Pinegreen is Virginia Pinegreen and Needlehold is a sticker, both manufactured by Kirk Co., Wautoma, Wisc.

^yn = 6. Within a column, means followed by the same letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range test.

was sawed off the base of the stem and the tree was immediately stood upright in a 20-liter bucket containing water. The value -5.0

MPa is near the damage threshold for redcedar (Hinesley, 1988). When a tree dries below this threshold, it 1) does not completely rehydrate when the base is recut and placed in water and/or 2) experiences unacceptable needle loss or discoloration following rehydration. Water potential of each tree was measured periodically for 12 days following return to water. Water consumption was determined regularly by filling each container to a designated mark, and evaporation was estimated with blank buckets. Needle loss at the conclusion of the experiment was measured by dropping the basal stem three times onto the concrete floor from a height of ≈ 0.5 m. Dislodged material was dried to a constant weight at 65C and standardized as grams per kg of initial fresh weight of the tree.

The experimental design was completely random with six treatments and six replications, totaling 36 trees. Because water potential measurements are relatively consistent within a tree (Hinesley, 1988; Montano and Proebsting, 1986), measurements were normally made on just one twig from the middle crown.

The experiment was repeated during the 1988 Christmas season, using similar methods and the same source of trees. Materials were applied on 7 Dec. between noon and 3:00 P.M. Temperature was 16 to 18C with a clear sky. Trees were harvested on 1 Jan. 1989 and immediately transported to Raleigh in a closed truck. Basal stems were recut, and trees were stood upright in buckets of water in the 20C classroom used previously. Water potential was measured when trees were removed from water the following morning (time = 0) and every 12 hr thereafter to establish the drying curve. Fluorescent lights operated 24 hr·day⁻¹. The time required to dry to -4.0 MPa was interpolated graphically for each tree.

In both experiments, drying rates were rapid for all treatments. In Expt. 1, pressure potential (ψ) decreased to -5.0 MPa in 43 hr for controls (Table 1). Pinegreen significantly ($P \leq 0.05$) reduced drying rate, with treatments involving one or two coats requiring 68 to 70 hr to reach -5.0 MPa.

Pinegreen plus Needlehold, both at a 1:20 ratio (v/v), or Pinegreen (1:20) followed by Needlehold (1:4) had drying rates similar to green colorant alone (Table 1). The drying rate for Pinegreen (1:20) plus Needlehold (1:4) was similar to that of controls in 1987.

Although trees quickly dehydrated after they were stood in water, four of the five coatings resulted in a better water status during the subsequent 12 days (Table 2). The water potential of control trees gradually decreased to -2.0 MPa during the 12 days after dehydration, whereas those painted with one or two coats of Pinegreen (1:20), Pinegreen (1:20) plus Needlehold (1:20), or Pinegreen (1:20) followed by Needlehold (1:4) maintained a relatively steady water potential near -0.5 MPa (Table 2). The single coat of Pinegreen (1:20) plus Needlehold (1:4) was intermediate between controls and the other treatments.

Water consumption was highest for control trees and those sprayed with combinations of Pinegreen (1:20) and Needlehold (Table 3). Consumption was lowest for trees sprayed with one or two coats of Pinegreen (1:20) alone. Needle loss, which was not significantly different among treatments (Table 3), showed considerable tree-to-tree variation within treatments.

Drying rates in 1988 (Expt. 2) were similar to those in 1987 (Table 1). Control trees dried fastest, followed closely by the combination of Pinegreen (1:20) plus Needlehold (1:4). The other four treatments significantly reduced drying rates, compared to controls.

In treatments that reduced the drying rate and/or improved water status after dehydration, the effect was apparently due to Pinegreen rather than Needlehold. One or two coats of Pinegreen was consistently best, whereas mixing higher rates (1:4) of Needlehold with the Pinegreen reduced its effectiveness. Despite the slower drying rate for certain treatments, all trees dried very fast. This result emphasizes that redcedar should be returned to water as soon as possible after cutting. Trees displayed for sale should be stood upright with bases in water.

Virginia Pinegreen imparted a darker green to redcedar foliage. Needlehold dried to a clear, shiny film and obscured the objectional prickliness of juvenile foliage. In this regard, Needlehold at a 1:20 ratio seemed just as effective as the 1:4 ratio. Even though latex-based green colorant reduced drying rates and water consumption following rehydration, the absolute improvement (hours) was small (Table 1). Therefore, it appears that the primary advantage of these and similar materials is cosmetic, enabling growers to market trees which look better and/or feel better to consumers.

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