Effects of Preservatives and Cold Storage on Postharvest Performance of Deciduous Holly Branches

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SUMMARY. Deciduous holly branches were visually rated over a period of 5 weeks to evaluate differences in display life between various cultivars of winterberry (*Ilex verticillata*) and japanese winterberry (*I. serrata*) x winterberry. Holly branches were naturally defoliated and the postharvest performance of the cut branches was therefore based on the quality and longevity of the fruit. Chemical treatments including floral preservative, floral preservative plus silver, and anti-transpirant were also evaluated. 'Bonfire' and 'Sunset' had the highest ratings for marketability based on the longevity and quality of their fruit. 'Bonfire' and 'Winter Red' had the highest fruit density per stem. Treatment with floral preservatives significantly increased the display life of holly branches. Preservative plus silver delayed deterioration later in the study, presumably by delaying the senescence of the fruit. Anti-transpirant treatment did not decrease solution uptake by the holly stems. Cold storage of dry branches at 0.00 ± 1.11 °C (32.0 ± 2.0 °F) did not significantly reduce branch display life if held for 23 days or less. Cut branches of all cultivars had a longer display life when stuck in sand and left outdoors in a lath house than when rated in vase solutions indoors. This study indicates that deciduous holly branches provide an attractive alternative cut branch for both interior and outdoor holiday displays.

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Specialty cut crops are most commonly flowers from herbaceous species, but can also include the flowers, fruit, stems, and foliage of woody plants (Armitage, 1993). Woody stems are generally grown for their aesthetically pleasing foliage, fruit, or flowers, however as a specialty cut crop they must also have adequate postproduction longevity. The longevity of cut stems is affected by production practices as well as proper postharvest treatment. Cut stems should be able to withstand periods of dry storage that allow for extended sales periods and facilitate long distance shipping. While specialty woody stems are becoming more commonplace, few recommendations exist for their postharvest care and handling (Nowak and Rudnicki, 1990).

The vase life of cut stems that have been removed from their source of water and carbohydrates may be extended by floral preservatives. Many floral preservatives provide a carbohydrate source as well as a biocide that prevents the growth of bacteria and fungi in the vase solution. Microorganisms in the vase solution can block xylem vessels and decrease uptake of water needed to maintain the turgidity of the cut stem and associated flowers or fruit. Ethylene may also have a detrimental effect on the vase life of cut stems, resulting in the abscission or senescence of leaves, flowers, and fruit. Some floral preservatives include an inhibitor of ethylene action, which is usually silver thiosulfate (Nowak and Rudnicki, 1990; Veen, 1979).

Deciduous hollies (*Ilex* spp.) are popular landscape plants providing winter ornamental interest in the form of brightly colored, shiny fruit. The long leafless branches with clusters of colorful fruit are also popular in the florist trade (Galle, 1997). Numerous cultivars are available with red, yellow, or orange-red fruit (Armitage, 1993). These cut branches are popular alone or in combination with evergreen branches or flowers as arrangements for the Thanksgiving or Christmas seasons. We evaluated the postharvest display life of various cultivars and a hybrid of winterberry, the deciduous holly most commonly used for cut branches. The objectives of this study were 1) to identify the cultivars with the best postharvest performance for indoor and outdoor displays and 2) to evaluate the effects of cold storage, floral preservative, silver, and anti-transpirant on the display life of holly stems.

Materials and methods

Naturally defoliated branches of healthy, well maintained deciduous hollies were cut and shipped 15 Nov. 1991 by personnel from Simpson Nursery Company, Vincennes, Ind. These included two cultivars of winterberry ('Winter Red' and 'Sunset') and a hybrid of winterberry and japanese winterberry ('Bonfire'). Branches were terminals plus side branches on older wood about 45.7 cm (17.99 inches) long. Harvested branches were placed loosely in plastic bags inside paperboard boxes and shipped overnight. Upon arrival, the boxes were placed immediately in refrigerated storage at 1.11 °C (34.0 °F) until 19 Nov. 1991, when the branches were grouped so that the largest and most heavily fruited were placed in replication 1 and the smallest branches with the fewest fruit were placed in replication 6. A fresh angled cut was made at the base that removed about 2.54 cm (1.0 inch) of the stem. Stems were then placed in plastic containers containing 200 mL (6.8 fl oz) of distilled water (control) or preservative solution and left on the laboratory bench for the duration of the experiment. Preservatives included 9.8 $mL \cdot L^{-1}$ (1.25 fl oz /gal) Rogard Gold with or without 7.8 $mL \cdot L^{-1}$ (1.0 fl oz/gal) Silgard RSystem Activator (Gard Environmental Group, Inc., Algonquin, Ill.). Rogard Gold is a preservative solution that contains complex carbohydrates, chelating agents, and a biocide. Silgard RSystem Activator is a silver containing solution that is used in conjunction with Rogard to treat ethylene sensitive flowers and foliage. Stems were also treated with an anti-transpirant [100 $mL \cdot L^{-1}$ (12.8 fl oz / gal) Wilt-Pruf; Wilt-Pruf Products, Inc., Essex, Conn.] by immersing the entire branch for 10 s, shaking off the excess, and then placing the stems in distilled water. Treatments were arranged as a split plot with cultivar as the whole plot and preservative as the split plot treatment with six replications. Means separation was by Duncan's multiple range test at $P = 0.05$. The laboratory

temperature was 21.00 ± 1.11 °C (69.8 ± 2.0 °F) and relative humidity was 38.0 ± 5.0% for the duration of the experiment. The room was illuminated with natural lighting from the windows and the average photosynthetic photon flux was 14.0 µmol·m^{-2}·s^{-1} (≈70 fc). The same room and conditions were used for all years. No attempts were made to optimize temperature, light or relative humidity because the experimental conditions were meant to closely simulate interior conditions within a home.

Holly branches were naturally defoliated and the postharvest performance of the cut branches was therefore based on the quality and longevity of the fruit. The cuttings were rated weekly for marketability and shine by four evaluators using a 1 to 10 scale. Marketability was a rating of the general appeal to consumers with the highest rating (10) having a dense display of brightly colored fruit, fresh appearance with no shriveled or discolored fruit, and a balanced branching pattern. A rating of 1 was considered not marketable because of sparse, discolored, shriveled or abscised fruit. Shine referred to the brightness or glistening of fruit as opposed to a dull appearance.

The chemical treatments were repeated in 1993, 1995, and 1996. Some cultivar variability between experiments may be attributed to the influence of production practices or weather conditions on postharvest quality. Cut branches were evaluated following four different growing seasons to minimize these effects. Experiments were not conducted in 1994 because bird predation in the field destroyed the experimental material. In 1993 and 1995, winterberry 'Afterglow' and 'Aurantiaca' were added, and in 1996 only 'Winter Red', 'Bonfire', 'Afterglow' and 'Cacapon' were evaluated. In the 1993 and 1996 experiments, fruit per stem were counted. Basal stem diameters were measured and used to calculate stem area, which was divided by fruit number to calculate fruit density. In 1993, 1995, and 1996 the amount of solution used by the branches each week was determined by measuring the volume of the vase solution. Following this measurement, solutions were brought back up to 200 mL with distilled water.

In a second study, cut branches of 'Winter Red' were kept in refrigerated storage at 0.00 ± 1.11 °C in closed, but not sealed, clear plastic bags for 6, 23, or 44 d. After storage, stems were recut, placed in distilled water, and left in containers on the lab bench. Stems were maintained and visually rated as previously described. Six replicate branches for each of the refrigerated storage periods were arranged in a randomized block design. This study was repeated in 1995.

A third study, conducted in Nov. and Dec. 1993 and repeated in 1995, involved inserting cuttings of all cultivars in moist sand in a lath house outdoors. Outside temperatures during the

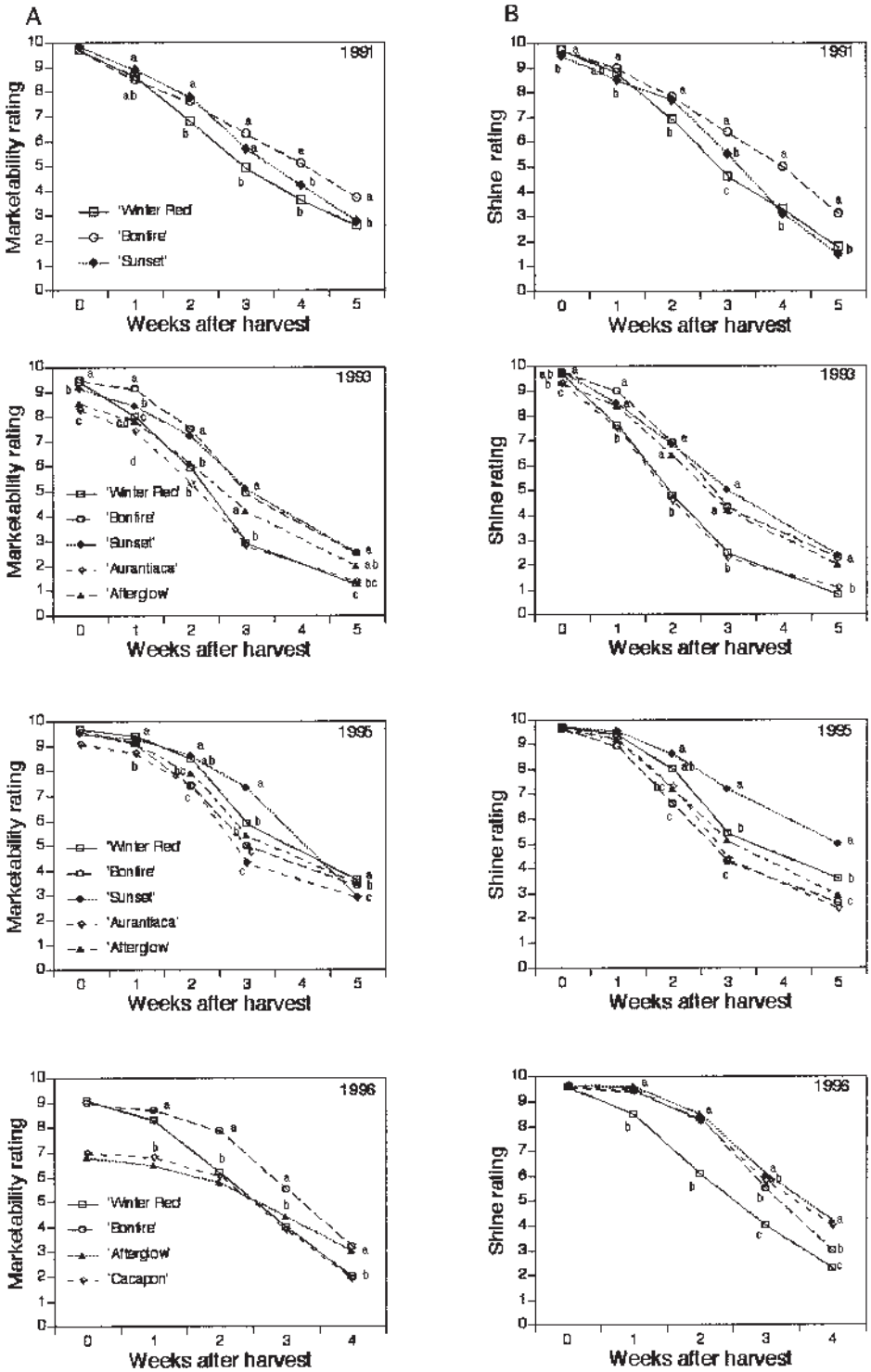

Fig. 1. Marketability (A) and fruit shine (B) ratings of deciduous holly branches at room temperature. Rating scale: 10 = very acceptable to 1 = not acceptable. Various cultivars as indicated were evaluated in 1991, 1993, 1995, and 1996. Values presented represent the average of six branches per cultivar.

study in 1993 ranged from –17.78 to 18.89 °C (0.0 to 66.0 °F). The average temperature for November was 4.78 °C (40.6 °F) and for December was –1.11 °C (30.0 °F). In 1995, temperatures ranged from –16.50 to 20.56 °C (2.3 to 69.0 °F). The average temperature for November was 2.22 °C (36.0 °F) and for December was –3.33 °C (26.0 °F). The purpose of this study was to evaluate how the cuttings would fare in outdoor arrangements. Weekly evaluations were conducted as previously described. The cultivars were arranged as a randomized complete block study with six replications.

Results

EVALUATION OF DISPLAY LIFE AND PRESERVATIVE TREATMENTS. Marketability and fruit shine declined similarly at room temperature in all 4 years over the 4 to 5 weeks of evaluation (Fig. 1). 'Bonfire' retained marketability longer than 'Winter Red' in 1991, 1993, and 1996, but in 1995, both cultivars declined similarly. In 1995 after 2 weeks at room temperature, 'Sunset' had greater marketability and fruit shine than the other cultivars tested. 'Aurantiaca' did not hold up as well as 'Sunset', 'Bonfire', and 'Winter Red' in the 2 years it was evaluated. Although 'Winter Red' was always rated as one of the most attractive cultivars during the first 3 weeks of the study, both marketability and fruit shine declined below other cultivars after 3 weeks.

'Bonfire' consistently absorbed more solution than other cultivars, except 'Winter Red' in 1993 and 1995 (Table 1). 'Bonfire' also had a higher fruit density than other cultivars in 1996. Cut branches treated with silver absorbed more preservative solution. Branches dipped in anti-transpirant did not differ from the control branches in the amount of solution taken up. There was no interaction between cultivar and treatment solution, therefore data presented is the average solution absorbed by all cultivars in a given treatment.

Although differences were not always significant for each week of observation, branches treated with preservative plus silver generally retained marketability and shine better than control branches in water (Fig. 2). Toward the end of the test period, the combination of preservative plus silver was superior in marketability and fruit shine to preservative treatment alone. Branches dipped in anti-transpirant retained fruit shine, particularly in 1996, but anti-transpirant was less effective in other years. The interaction of cultivar and postharvest treatment for marketability was significant for different reasons each year and data is presented for the mid-December date only (Fig. 3). In 1991, preservative plus silver resulted in superior marketability of 'Winter Red' and 'Sunset' with little difference among the other treatments. With 'Bonfire', preservative alone or in combination with silver improved marketability. In 1993, anti-transpirant treatment improved marketability of 'Bonfire', 'Sunset', and 'Afterglow', but none of the treatments influenced 'Winter Red' or 'Aurantiaca'. In 1995, preservative and the combination of silver plus preservative improved marketability of 'Winter Red' and 'Afterglow', while only preservative plus silver was effective with 'Bonfire' and 'Sunset'. While the anti-transpirant treatment had no effect on the other cultivars, it improved marketability of 'Sunset' in 1995. In 1996, preservative and preservative plus silver improved marketability of 'Winter Red', 'Afterglow' and 'Cacapon', but had no effect on 'Bonfire'. In 1996, the marketability of all cultivars was improved by anti-transpirant treatment.

EFFECTS OF STORAGE ON DISPLAY LIFE. Storage at 0.00 ± 1.11 °C for 6 or 23 d had little effect on marketability or retention of fruit shine (Fig. 4). However, 44 d of cold storage significantly reduced both marketability and shine and these branches reached minimal ratings after only 15 d at room temperature.

EVALUATION OF CUT STEMS FOR OUTDOOR DISPLAYS. In 1993, cut branches were stuck in sand out of doors in a lath house to evaluate their potential for outdoor arrangements. All cultivars retained their initial marketability and fruit shine over the 5 weeks of outdoor exposure. 'Aurantiaca' was rated with lower marketability than other cultivars due to off color and some dark fruit initially with this difference persisting for the duration of the study. This study was repeated in 1995 with similar results (data not shown).

Discussion

All holly branches lasted for the 4 to 5 week evaluation period, which is a substantial display life for a cut branch (Armitage, 1993). After 5 weeks of evaluation, only 'Aurantiaca' and 'Winter Red' had quality ratings (marketability or shine) of 1 or unmarketable and that occurred only in 1993. 'Bonfire' and 'Sunset' had consistently higher ratings than the other cultivars in both marketability and shine. 'Winter Red' was also one of the most attractive displays in most years but it had a sharper decline in quality after 3 weeks than 'Bonfire' or 'Sunset'. Both 'Bonfire' and 'Winter Red' had much higher fruit density than 'Sunset'. When considering both fruit density and quality ratings, 'Bonfire' and 'Winter Red' would make the most attractive indoor displays either alone or in combination with other foliage or flowers. The fruit of 'Bonfire' and 'Winter Red' are vividly red making nice displays for the Christmas season

Table 1. Influence of cultivar and preservative treatments on the solution absorbed and fruit density of cut deciduous holly stems.

	Solution absorbed (mL)[z]			Fruit density (no./cm² branch area)[y]	
Cultivar	**1993**	**1995**	**1996**	**1993**	**1996**
Winter Red	217 a[x]	136 a	135 b	875 a	790 b
Bonfire	234 a	137 a	190 a	934 a	1441 a
Sunset	150 b	101b	---	259 c	---
Aurantiaca	661 b	104 b	---	829 a	---
Afterglow	161 b	43 b	134 b	525 b	199 c
Cacapon	---[w]	---	124 b	---	265 c
Treatment					
Control	164 bc[v]	98 b	141 bc		
Preservative	191 b	139 a	153 ab		
Silver plus preservative	231 a	143 a	163 a		
Anti-transpirant	153 c	94 b	127 c		

[z]1 mL = 0.034 oz.
[y]1 cm² = 0.155 inch².
[x]Means separated by Duncan's multiple range test, $P = 0.05$.
[w]Cultivar not tested this year.
[v]Mean value for all cultivars evaluated that year.

while fruit of 'Sunset' are a deep, reddish orange and may be more desirable for Thanksgiving arrangements. Cut branches of winterberry are used by florists, while japanese winterberry is more commonly grown as a garden ornamental (Galle, 1997).

'Bonfire' stems took up more vase solution than the other cultivars, which may have contributed to its increased fruit quality. During 1993 and 1996, anti-transpirant treatment of 'Bonfire' stems increased its marketability rating. While anti-transpirant treatments are used to block stomata and reduce transpiration, these applications did not consistently affect display life and most branches did not use any less water than the controls. The number of stomata per fruit has been reported to differ significantly among cultivars of sweet cherry (*Prunus avium*) (Peschel et al., 2003). While the number of stomata on the holly fruit and stems was not determined, cultivar differences following anti-transpirant application may have been the result of differences in stomatal density.

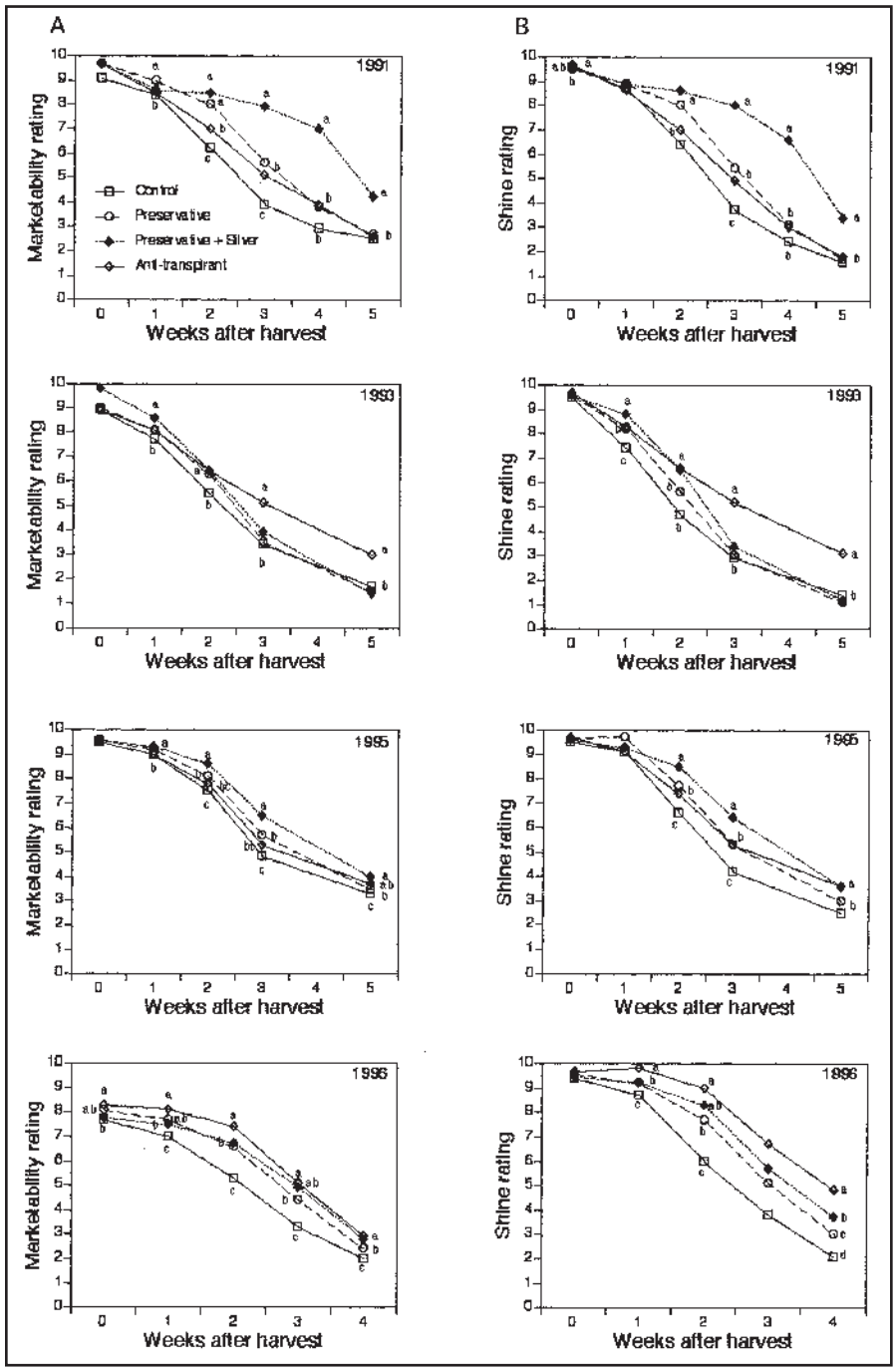

Fig. 2. Marketability and fruit shine ratings of deciduous holly branches as influenced by chemical treatments at room temperature. Rating scale: 10 = very acceptable to 1 = not acceptable. Values presented represent the average of all cultivars evaluated and include six stems of each cultivar per treatment.

Branches in preservative plus silver were not always ranked significantly higher than other treatments, but in 3 of the 4 years it increased stem quality at the later evaluation dates. While deciduous holly has been reported to be sensitive to ethylene (Nell and Reid, 2000), if not exposed to ethylene during the early display period, the silver treatment may not have an enhanced effect over preservative alone. Fruit become more sensitive to ethylene as they age (Liu et al., 1985). As the holly fruit aged, the silver may have delayed senescence and led to a slower decline in fruit quality.

Floral preservatives have previously been reported to have a limited effect on extending the vase life of deciduous holly species (Nell and Reid, 2000). It is clear that the cultivars tested had long display lives, especially when evaluated outdoors. This indicates that the lower outdoor temperatures, which would decrease respiration and delay fruit senescence, had a greater impact on improving display life than supplementing carbohydrate levels with preservatives. These cooler temperatures should also reduce the detrimental effects of endogenous ethylene on fruit senescence.

Deciduous holly stems provide an attractive cut branch for both interior and outdoor holiday displays. The display life of these hollies is quite long and cold dry storage can be used to extend the time the branches are available into January and February. Commercial availability should improve as more information becomes available for the production and postharvest handling of these branches.

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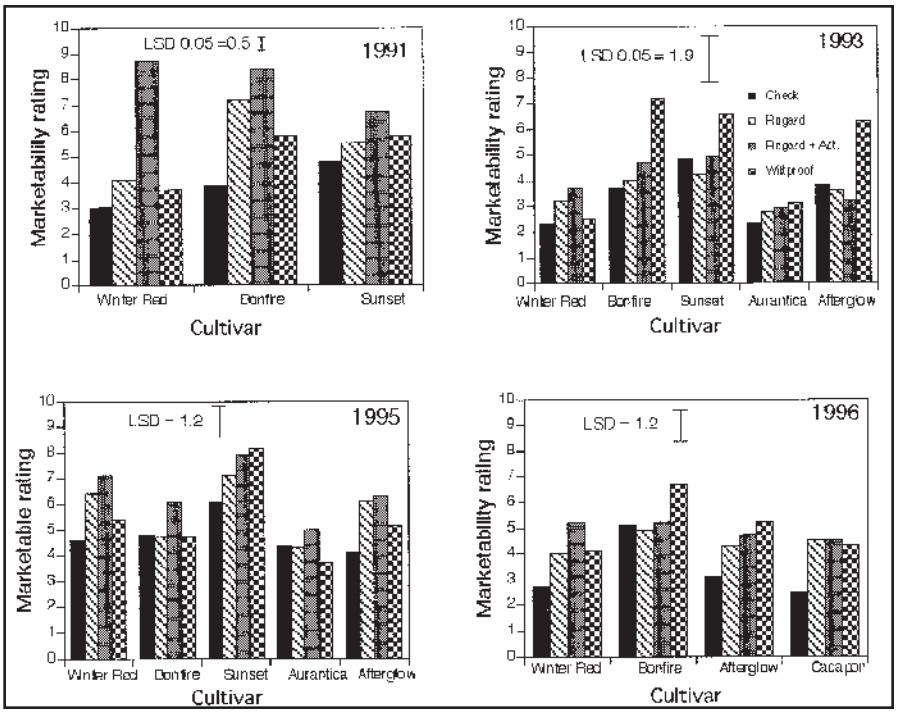

Fig. 3. Interaction of deciduous holly cultivars and preservative chemicals on marketability of cut branches in mid-December after about 3 weeks at room temperature. Rating scale: 10 = very acceptable to 1 = not acceptable. Mean separation determined by least significant difference (LSD) at $P = 0.05$.

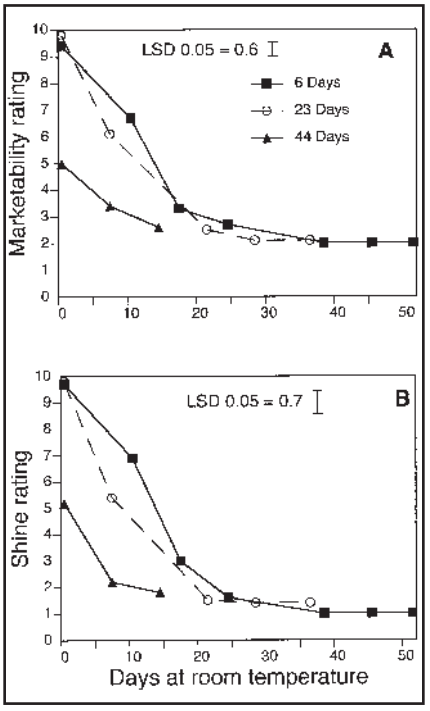

Fig. 4. Influence of various duration of refrigerated storage on marketability (A) and fruit shine (B) of 'Winter Red' deciduous holly branches exposed to room temperatures. Rating scale: 10 = very acceptable to 1 = not acceptable. Mean separation determined by least significant difference (LSD) at $P = 0.05$.

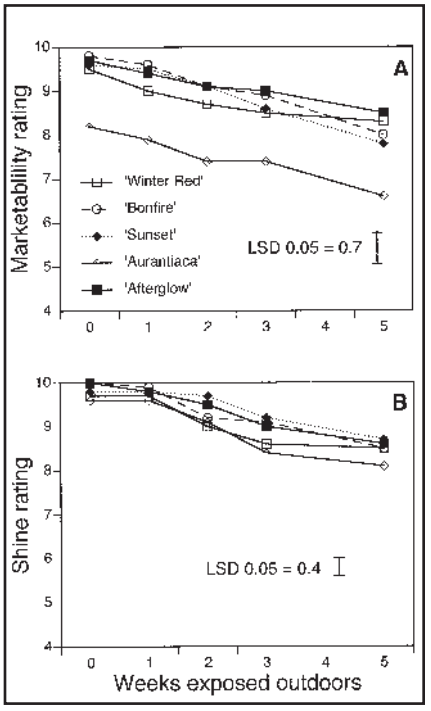

Fig. 5. Marketability (A) and fruit shine (B) ratings of cut branches of five deciduous holly cultivars exposed to outdoor conditions for 5 weeks. Rating scale: 10 = very acceptable to 1 = not acceptable. Data presented is for experiments conducted in 1993 and includes six branches per cultivar. Mean separation determined by least significant difference (LSD) at $P = 0.05$.