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Silver Thiosulfate Prevents Ethylene-induced Abscission in Holly and Mistletoe

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Abstract. Low concentrations of ethylene induced abscission of leaves and berries from cut branchlets of English holly (*Ilex aquifolium* L.) and American mistletoe [*Phoradendron tomentosum* (DC.) Engelm. ex Gray ssp. *macrophyllum* (Engelm.) Wiens]. Application of 1 μmol of Ag⁺ per branchlet (as the anionic silver thiosulfate complex, STS) via the transpiration stream was found to retard this abscission. A higher application rate (4 μmol Ag⁺ per branchlet) stimulated leaf abscission in mistletoe. There were marked differences in sensitivity to ethylene among various types of holly.

Holly and mistletoe are used traditionally for decoration during the Christmas season. Both are, however, prone to leaf and berry abscission during transport and marketing. This renders them unattractive and limits full realization of their aesthetic and commercial potential. Commercial holly producers presently treat the harvested branches with naphthalene acetic acid (NAA) to reduce abscission of leaves and berries during marketing (Roberts and Ticknor, 1970), but this procedure has been observed to be only partially effective (P. Schmidt, personal communication).

Abscission of plant organs is a frequent response to the presence of elevated levels of C₂H₄ (Reid, 1985) that may accumulate in the atmosphere surrounding harvested produce as a result of endogenous C₂H₄ production or as a consequence of air pollution (Sherman, 1985). In holly, infection of branches with *Phytophthora ilici* aggravates organ abscission, apparently because the pathogen induces C₂H₄ production by the plant (D. Coyier, personal communication).

The inhibition of C₂H₄ action by silver ion (Ag⁺) (Beyer, 1976a, 1976b) has been used as a practical tool to increase the longevity of some cut-flower species (Mor et al., 1984a, 1984b; Veen and van de Geijn, 1978) and

to prevent organ abscission in potted plants (Cameron and Reid, 1981; Cameron and Reid, 1983). This study was carried out to examine the role of C₂H₄ in abscission of leaves and berries from holly and mistletoe branchlets and to test the possible usefulness of silver thiosulfate (STS).

Plant materials were collected on the Davis campus of the Univ. of California and from garden trees in the San Francisco area. A single species of mistletoe was studied [*Phoradendron tomentosum* (DC.) Engelm. ex Gray ssp. *macrophyllum* (Engelm.) Wiens]. The hollies investigated were hex

aquifolium L. (English holly), *I. cornuta* Lindl. (Chinese holly), *I. cornuta* cv. Burfordii (Burford holly), *I. × altaclarensis* Wilsonii, (Wilson holly), and *I. vomitorii* Ait. cv. Nana (dwarf Yaupon holly). In one experiment, we compared branchlets from spiny and spineless plants of Burford holly. The mean numbers of leaves on the 15- to 20-cm branchlets were seven for mistletoe and 11 for holly.

The experiments examined the ethylene response of the different Christmas greens, and the effect on the quality of control and ethylene-treated branchlets of pulsing with STS or treatment with a cut-flower preservative. In all but one experiment, branchlets were placed in 10-ml glass test tubes containing deionized water (DI) or 4% (w/v) sucrose plus 200 ppm Physan 20 (a mixture of quaternary NH₄⁺ compounds) in DI. In the other experiment, mistletoe branchlets were placed in the 10 × 20-cm perforated plastic bags used commercially for marketing mistletoe branchlets. Each bag had twenty-four 6-mm-diameter holes. Three branchlets were placed in each bag, and solutions were supplied to the cut stem ends in presoaked cotton balls. The solutions were 1% (w/v) Floralife (a commercial flower preservative) and 0.4 or 4 mM STS in 1% (w/v) Floralife. STS was prepared as described by Reid and Farnham (1980).

For experiments when STS was supplied as a pulse taken up via the transpiration stream, the uptake of Ag⁺ was measured by weighing the uptake vial (which contained 10 mM STS). A 0.1-g decrease in weight was taken to indicate uptake of 1 μmol Ag⁺.

Fig. 1. Leaf abscission from mistletoe branchlets, as a function of STS uptake, 3 (○) and 13 (●) days after commencement of a 2-day exposure to 2 ppm C₂H₄. Points are means of three replicates. Curves depict the best-fit regression functions after the 3rd (—) and 13th (---) days.

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Table 1. Analysis of variance for effects of ethylene on leaf retention by English, Chinese, and two selections of Burford hollies. Nonsignificant single-degree-of-freedom contrasts are not shown.

Source	df	Sum of squares	Mean square	F value
Replication	2	407	203	0.50 ^{NS}
Ethylene (E)	3	42,554	14,184	35.41*
Control vs. ethylene	1	5,162	5,162	12.89*
Cultivar (C)	3	64,150	21,383	53.39*
Burford vs. others	1	7,500	7,500	18.70*
E × C	9	20,300	2,255	5.63*
Chinese, control vs. ethylene	1	14,502	14,502	36.21*
English, control vs. ethylene	1	14,393	14,393	35.94*
Error	30	12,015	400	
Time (T)	1	1,492	1,492	24.05*
E × T	3	414	138	2.22 ^{NS}
C × T	3	1,735	578	9.32*
Spiny vs. spineless Burford, day 8	1	1,241	1,241	20.01*
E × C × T	9	2,017	224	3.61*
Spineless Burford, control vs. ethylene, day 8	1	4,064	4,064	65.55*
Error	32	1,985	62	---
Total	95	147,073	---	---

*^{NS}, Significant at $P = 0.01$ or nonsignificant, respectively.

Fig. 2. Effect of STS pretreatment (3 $\mu\text{mol}/\text{branchlet}$) on the response of English holly to a 5-day exposure to 2 ppm C_2H_4 .

When the branchlets had taken up the desired amount of STS, their bases were rinsed with DI and they were transferred to test tubes containing DI.

When used, C_2H_4 was supplied to holly or mistletoe branchlets held in glass tanks (one tank, 50 cm long $\times$ 25 cm wide $\times$ 30 cm high, per concentration). The gas mixture was passed through the tank at a rate of $\approx 35 \text{ liter} \cdot \text{hr}^{-1}$. Control branchlets were placed in a tank through which air alone was passed. Before STS-treated material was exposed to C_2H_4 , the branchlets were held overnight in DI to allow internal redistribution of Ag^+ .

All experiments were conducted in an air-conditioned ($\approx 22^\circ\text{C}$) laboratory. A randomized complete block design with time as a sub-treatment was used for each experiment. There were three replications, with one sprig per replicate, in each experiment. Percentage data were transformed ($X_i = \arcsin X_i$) for analysis.

Mistletoe branchlets held in air lost 60% of their leaves after standing for 13 days in DI water (Fig. 1). Treatment with 2 ppm C_2H_4 caused this much abscission in 3 days; by day 13, C_2H_4 -treated branchlets had lost $> 80\%$ of their leaves. Application of from

0.2 to 2 μmol STS per branchlet effectively prevented C_2H_4 -induced leaf abscission in mistletoe, even 13 days after exposure to C_2H_4 (Fig. 1). Four micromoles of Ag^+ per branchlet induced leaf abscission, presumably as a result of Ag^+ toxicity, or perhaps in response to the stimulated production of ethylene that has been observed in other vegetative tissues treated with Ag^+ (Gavinlertvatana et al., 1980).

Application of STS via the transpiration stream (1 μmol) or in a soaked cotton ball (0.4 mm) prevented C_2H_4 -stimulated leaf abscission from mistletoe packaged in plastic bags, whether or not a cut-flower preservative was included in the ball. A higher concentration of STS (4 mM) stimulated leaf shedding (to 40% leaf loss in 3 days).

Chinese and English hollies were very sensitive to C_2H_4 (Tables 1 and 2); 0.6 ppm was sufficient to cause almost complete defoliation of English holly following a 3-day exposure. Burford holly was much less sensitive to C_2H_4 (Tables 1 and 2); the spineless form of this species was less affected by C_2H_4 than was either English or Chinese holly, while the spiny form was unaffected by any of the C_2H_4 concentrations tested. Differential responses were also found among other hollies tested. Whereas all the leaves of dwarf Yaupon holly abscised following a 3-day exposure to 35 ppm C_2H_4 , Wilson holly branchlets were unaffected (data not shown).

Silver thiosulfate treatment of English holly substantially reduced the leaf and berry abscission caused by a 5-day exposure to 2 ppm C_2H_4 (Fig. 2). Similar results were obtained with other C_2H_4 -sensitive cultivars (data not shown).

The studies described here indicate the potential importance of C_2H_4 in the postharvest life of cut holly and mistletoe. Relatively short exposures to air containing concentrations of C_2H_4 known to occur in supermarkets and other retail outlets caused unsightly loss of leaves and berries (unpublished data). The dramatic reduction in C_2H_4 -induced leaf and berry abscission resulting from STS pretreatment indicates a means of controlling

Table 2. Mean percentages of leaves retained by Chinese, English, and two selections of Burford hollies after 3 or 8 days of exposure to ethylene.

Ethylene concn (ppm)	Holly type			
	Burford (spineless)	Burford (spiny)	Chinese	English
<i>Three-day exposure</i>				
0	100	100	100	100
0.6	71	100	13	18
15	96	95	0	0
120	93	100	5	7
<i>Eight-day exposure</i>				
0	100	100	96	100
0.6	67	100	2	10
15	38	92	0	0
120	44	100	0	7

this problem. Commercial use of STS would require care to avoid stimulation of abscission due to excess Ag⁺. A level of $\approx 1 \mu\text{mol}$ per branchlet appears to be a practical treatment target.

The variability in the response to C₂H₄ of closely related holly cultivars (Burford holly is a cultivar of Chinese holly) is particularly interesting because it indicates the potential, at least in this species, of breeding for C₂H₄ resistance.

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Controlled Atmosphere Effects on Physical Changes and Ethylene Evolution in Harvested Okra

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Abstract. Pods of okra (*Abelmoschus esculentus* L. Moench) stored in an atmosphere of 5% O₂ and 10% CO₂ at 10 $\pm$ 1°C were compared with pods stored in air at the same temperature to determine the effects of storage environment on physical characteristics and ethylene evolution of the pods. Controlled-atmosphere- (CA) stored pods lost less weight, retained total solids and chlorophyll better, and had a higher mucilage viscosity than air-stored pods. Toughness, fibrousness, and incidence of microbial decay were lower in CA-stored pods than in air-stored pods. No differences were seen in the levels of alcohol-insoluble solids or discoloration of the cut surface between pods from the two storage environments. Ethylene evolution was lower in CA- than air-stored pods.

Fresh okra is a popular ingredient of soups and stews where a highly viscous consistency is desired.

In addition to its being a good source of a viscous mucilage, okra also provides fiber and protein (9) and vitamin C (1) in the diet. Fresh okra has a high respiration rate and is extremely perishable (8). Quality loss in harvested okra is usually manifested as shriveling, toughening, and chlorophyll degradation (16). These conditions detract from the appearance of the pods, leading to rejection by consumers, even if nutritional quality was not affected adversely.

Spraying fresh okra with potassium phos-

phate (11) and cycocel (16) has been found effective in reducing postharvest loss, but only under experimental conditions. Modified-atmosphere (MA) storage has been effective in extending storage life (3) and ameliorating chilling injury (10) of okra, but there is little information concerning the effects of modification of the storage atmosphere on fresh okra quality. The objective of this study was to determine the effects of controlled-atmosphere (CA) storage on physical characteristics and ethylene evolution in okra.

'Clemson spineless' Okra was grown on the St. Paul campus of the Univ. of Minnesota under commercial conditions. Fruit were harvested 6 days after anthesis, trimmed, immediately forced-air-cooled (to $\approx 12^\circ\text{C}$) and placed in a 69 $\times$ 37 $\times$ 37-cm (L $\times$ W $\times$ H) plexiglass chamber that was then sealed. The recommended CA for okra, 5% O₂ plus 10% CO₂, with the remainder N₂ (12), was prepared by mixing commercially bottled gas from high-pressure cylinders and conducted into each chamber. A system of solenoid valves and timers controlled the flow of gas into the chambers to provide one complete change of the atmosphere about every 16 hr. Temperature was held at 11 $\pm$ 1°C and 90% to 93% RH. Pods stored at the same temperature and relative humidity were used as controls, which received one complete change of air about every 16 hr. Each test consisted of a single treatment and control chamber with three tests per year for 2 years.

To determine ethylene levels, a gas sample was withdrawn from each chamber at the start of storage and at 1-hr intervals for 8 hr and then at 4-hr intervals for 16 hr and ana-

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