Postharvest Characteristics of Geraldton Wax Flowers

Daryl C. Joyce
Western Australian Department of Agriculture, Baron-Hay Court, South Perth, W.A., 6151, Australia

Additional index words. Chamelaucium uncinatum, ethylene, silver thiosulfate, storage, vase-life, floral preservative, irradiation

Abstract. Abscission of flowers of Geraldton wax (Chamelaucium uncinatum Schau., Myrtaceae) exposed to ethylene was prevented by pulsing with silver thiosulfate. Both a short pulse (15 min, 4.0 mM Ag+) at 25°C and an overnight pulse (0.5 mM Ag+) at 2° were effective treatments. Silver thiosulfate did not improve the vase-life of flowers held in air. Gamma irradiation (6Co source), an insect control measure, resulted in a reduction in vase-life; even at doses as low as 0.05 kGy. Vase-life of Geraldton wax flowers was not affected by prior storage for up to 2 weeks at 0° to 2°. Iprodione pretreatment (1 g·liter⁻¹, 30-sec dip) for Botrytis cinerea Pers. control improved the vase-life of flowers stored for 2 weeks. A preservative solution containing sucrose (1% to 3% w/v) and 8-hydroxyquinoline sulfate (200 mg·liter⁻¹) increased the vase-life of Geraldton wax flowers. Higher sucrose levels (>5% w/v) may cause desiccation of foliage and excessive nectar secretion from floral nectaries. Chemical name used: 3-(3,5-dichlorophenyl)-N-(1-methyl-ethy1)-2,4-dioxo-1-imidazolidin-carboxamide (iprodione).

Geraldton wax is a native Australian plant (1, 12) of increasing importance in the international cut flower industry. Substantial quantities of this flower are produced in Australia, California, and Israel. Geraldton wax can also be marketed as a potted flowering plant (6, 12).

Little study has been carried out on the postharvest characteristics of Geraldton wax. Problems warranting attention include: a) shattering (abscission of whole flowers from the stem), b) live insects in consignments of Geraldton wax, c) cold storage to extend the postharvest life, and d) floral preservatives to maintain flower quality.

Shattering is probably the most serious problem with Geraldton wax. Floral abscission has been attributed to accumulation of C₂H₄ in the surrounding environment. The silver ion (Ag⁺) is known to delay a) fading of carnations (10, 11, 14), b) flower drop from potted flowering plants (2), and c) leaf abscission from cut foliage (5).

In this study, Ag⁺ was applied to Geraldton wax by pulsing with the silver thiosulfate complex (STS) (11). Other postharvest treatments investigated were: a) γ-irradiation (60Co source) as a potential insect control treatment, b) cold storage as it affects respiration rates and subsequent vase-life, and c) a floral preservative to extend the vase-life of Geraldton wax.

Materials and Methods

Plant material. Geraldton wax flowers were harvested at dusk over the 1986 winter-spring flowering season. The plants were growing in Dept. of Agriculture grounds. Harvested branches were held overnight at room temperature (~15°C) with their stems in a solution of 200 mg·liter⁻¹ 8-hydroxyquinoline sulfate (HQs)—a quinoline compound with antibacterial activity (7). Branches were subsequently subdivided into sprigs 15 to 20 cm long. Individual sprigs bore ~20 floral organs (buds and flowers), and were selected with 50% to 75% of the flowers fully open.

Received for publication 17 Apr. 1987. The use of specific chemicals in this study does not imply endorsement over similar products with like properties. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.
jecting samples of air from the jars into the air stream passing through the gas analyzer (3).

Storage. To test the effect of dry storage on the vase-life of Geraldton wax, flowers were held for 1, 2, 4, or 6 weeks at 0°C prior to vase-life evaluation. Dry-stored flowers were wrapped in polyethylene film, with random perforation for air exchange. Control of *Botrytis cinerea* Pers. with iprodione (complete immersion for 30 sec in 1 g·liter⁻¹ Rovral [May and Baker Agrochemicals, West Footscray, Victoria, Australia]) was evaluated in another experiment testing the relative benefits of wet (stems in 200 mg·liter⁻¹ HQS) and dry storage at 2°.

Vase-life evaluation. Treatment effects were evaluated in a constant temperature room (20°C) with an average light flux at flower level of 14 μmol·s⁻¹·m⁻² (from cool-white fluorescent lamps), a 12-hr photoperiod, and an average air speed of 0.6 m·s⁻¹.

Geraldton wax sprigs, one per vase, were held in a preservation solution of 2% (w/v) sucrose plus 200 mg·liter⁻¹ HQS during vase-life assessment. Preliminary tests (data not shown) indicated that this preservation formulation extended the vase-life of Geraldton wax, relative to deionized water alone. The effect on vase-life of varying sucrose concentrations (0% to 20% w/v) is reported in Results. The end of vase-life (flower life) was judged as that point when more than one-half of the open flowers on individual sprigs had begun to close (i.e., petals coming together) and/or when extensive abscission of floral organs (buds, flowers) rendered the sprigs unattractive. In some experiments, foliage life was assessed separately; end of foliage life was associated with chlorosis and/or desiccation of the leaves.

Statistical analysis. Data were analyzed by analysis of variance (ANOVA). Percentage data were transformed (V/x + 100) to obtain approximately normally distributed data sets for ANOVA. Least significant differences (P < 0.05) and/or SDS are presented where appropriate. Replication ranged from three to six in various experiments.

Results

Silver pulsing. A 4-hr exposure to C₂H₄ resulted in a subsequent increase in flower abscission relative to ungassed (control) Geraldton wax sprigs and those exposed to C₂H₄ for 1 or 2 hr (Fig. 1A). Exposure to C₂H₄ for 20 hr resulted in abscission of almost all flowers. Extensive flower abscission occurred within 24 hr of the onset of gassing with C₂H₄. Flowers abscised at an abscission zone between the base of the calyx tube and the top of the pedicel.

Pulsing Geraldton wax with Ag⁺ (as STS) the day before exposing the sprigs to C₂H₄ gave almost complete protection against subsequent shattering (Fig. 1B). As little Ag⁺ as 0.1 μmol·g⁻¹ fresh weight was an effective treatment against C₂H₄-induced flower abscission.

The effect of different levels of Ag⁺ on Geraldton wax vase-life was investigated by pulsing the flowers with up to 6 μmol·g⁻¹ fresh weight. STS did not improve the vase-life of flowers (Fig. 1C). Uptake of Ag⁺ beyond about 0.6 μmol·g⁻¹ fresh weight caused a decrease in vase-life. Symptoms of Ag⁺ toxicity were closure of the flowers and increased flower abscission.

In a comparison of commercial STS treatments, neither pulsing at room temperature (4 mM Ag⁺, 20°C) for up to 60 min nor pulsing overnight (0.5 and 1.0 mM Ag⁺, 2°) affected flower vase-life relative to the untreated control (Table 1). Although significant (P < 0.05) effects of Ag⁺ pulsing on foliage vase-life were recorded, the STS treatments did not consistently improve foliage life (Table 1).

Table 1. Vase-life of Geraldton wax pulsed with 4 mM Ag⁺ for 5, 10, 20, or 60 min at 20°C or pulsed with 0.5 and 1.0 mM at 2°.

<table>
<thead>
<tr>
<th>Ag⁺ treatment</th>
<th>Flowers</th>
<th>Foliage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated, 20°C</td>
<td>18.3 ns</td>
<td>14.0 abc</td>
</tr>
<tr>
<td>5 min, 4 mM Ag⁺, 20°</td>
<td>15.3</td>
<td>12.5 ab</td>
</tr>
<tr>
<td>10 min, 4 mM Ag⁺, 20°</td>
<td>14.5</td>
<td>12.3 a</td>
</tr>
<tr>
<td>20 min, 4 mM Ag⁺, 20°</td>
<td>16.3</td>
<td>15.0 abcd</td>
</tr>
<tr>
<td>60 min, 4 mM Ag⁺, 20°</td>
<td>15.5</td>
<td>16.0 bcd</td>
</tr>
<tr>
<td>Overnight, 0.5 mM Ag⁺, 2°</td>
<td>16.5</td>
<td>17.5 cd</td>
</tr>
<tr>
<td>Overnight, 1.0 mM Ag⁺, 2°</td>
<td>16.5</td>
<td>18.3 d</td>
</tr>
</tbody>
</table>

*Mean separation by LSD (P < 0.05) = 3.5 days (replication 4-fold).
*ns = no significant differences (replication 4-fold).
*Ag⁺ applied as STS complex.

When short-term (15 min, 4 mM Ag⁺, 25°C) and long-term (overnight, 0.5 and 1.0 mM Ag⁺, 2°) pulsing treatments were followed by exposure to C₂H₄, subsequent flower abscission was reduced and the vase-life was increased (Table 2). Although the blooms used in this experiment were of poor quality (short vase-life) and exposure to C₂H₄ after pulsing resulted in some flower abscission, the protection conferred by STS pulsing was substantial (=66% flower retention).

In investigating STS inhibition of C₂H₄-induced flower abscission, I noticed that open flowers were retained to a notably
Table 2. Retention of floral organs (buds and flowers) 24 hr after \( \text{C}_2\text{H}_4 \) treatment and vase-life* after gassing of untreated and \( \text{Ag}^+ \)-pulsed Geraldton wax.

<table>
<thead>
<tr>
<th>Treatments(a)</th>
<th>Floral organ retention* (% of initial number)</th>
<th>Vase-life* (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated, (-\text{C}_2\text{H}_4)</td>
<td>93 c 4.3 b</td>
<td>(-\text{C}_2\text{H}_4)</td>
</tr>
<tr>
<td>Overnight pulse, (-\text{C}_2\text{H}_4)</td>
<td>92 c 4.0 b</td>
<td>(-\text{C}_2\text{H}_4)</td>
</tr>
<tr>
<td>15-min pulse, (-\text{C}_2\text{H}_4)</td>
<td>97 c 3.3 b</td>
<td>(-\text{C}_2\text{H}_4)</td>
</tr>
<tr>
<td>Untreated, (+\text{C}_2\text{H}_4)</td>
<td>3 a 0.2 a</td>
<td>(+\text{C}_2\text{H}_4)</td>
</tr>
<tr>
<td>Overnight pulse, (+\text{C}_2\text{H}_4)</td>
<td>64 b 3.3 b</td>
<td>(+\text{C}_2\text{H}_4)</td>
</tr>
<tr>
<td>15-min pulse, (+\text{C}_2\text{H}_4)</td>
<td>67 b 3.2 b</td>
<td>(+\text{C}_2\text{H}_4)</td>
</tr>
</tbody>
</table>

*Floral preservative: 2% sucrose plus 200 mg-liter\(^{-1}\) HQS.
*\(\text{Ag}^+\) applied as STS complex.
*3 (\(\text{Ag}^+\)) \(\times\) 2 (\(\text{C}_2\text{H}_4\)) factorial, replication 6-fold.
*Data transformed for ANOVA, mean separation (\(\text{Ag}^+ \times \text{C}_2\text{H}_4\)) by LSD \((P < 0.05) = 7.2\%\).
*Mean separation (\(\text{Ag}^+ \times \text{C}_2\text{H}_4\)) by LSD \((P < 0.05) = 1.1\) days.

greater extent than the flower buds. This observation suggests that \(\text{Ag}^+\) was preferentially directed to flowers, possibly as a consequence of greater transpiration. Experience in Israel has indicated that redistribution of \(\text{Ag}^+\) to buds requires considerable time (J. Faragher, personal communication).

**Gamma irradiation.** Irradiation of Geraldton wax flowers markedly decreased flower vase-life over a dosage range of 0 to 2.0 kGy (Fig. 2). Doses between 0.25 and 2.0 kGy did not further decrease flower vase-life. Foliage vase-life decreased in response to increasing irradiation doses in a similar fashion to that described for flower vase-life (Fig. 2).

**Respiration and storage.** The respiration rate of Geraldton wax held at 20°C fell markedly over the first 2 or 3 days after harvest (Fig. 3 upper). Thereafter, the respiration rates were more constant. A small increase in respiration towards the end of the study was attributable to *Botrytis* proliferation. Decreased temperature brought about a large decline in the respiration rate (Fig. 3 lower). Following equilibration to temperature (day 1), \(Q_{10}\) values of 4.8 and 3.3 were estimated for the temperature ranges of 0° to 10° and 10° to 20°, respectively. On day 1 of storage, energy released in respiration (assuming sucrose to be the ultimate respiratory substrate) was calculated to be 0.21, 0.87, and 3.02 kJ·kg\(^{-1}\)·hr\(^{-1}\) at 0.9°, 10.1°, and 20.4°, respectively.

Storage of Geraldton wax flowers for up to 2 weeks at 0°C resulted in no loss of vase-life (Table 3). Storage for 4 and 6 weeks, however, resulted in extensive flower abscission in association with prolific growth of *Botrytis*. *Botrytis* infection was particularly bad in the 1986 season because of consistently wet weather during flower development. The fungus was observed...
Table 3. Vase-life of Geraldton wax following 0, 1, 2, 4, or 6 weeks of storage at 0°C.

<table>
<thead>
<tr>
<th>Storage duration (weeks)</th>
<th>Vase-life (days)</th>
<th>Storage duration (weeks)</th>
<th>Vase-life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7.3 b</td>
<td>1</td>
<td>7.7 b</td>
</tr>
<tr>
<td>1</td>
<td>7.7 b</td>
<td>2</td>
<td>9.7 c</td>
</tr>
<tr>
<td>4</td>
<td>2.0 a</td>
<td>6</td>
<td>3.0 a</td>
</tr>
</tbody>
</table>

*Mean separation by LSD (P < 0.05) = 1.6 days (replication 3-fold).

Table 4. Effects of wet and dry storage and iprodione dipping on the vase-life of Geraldton wax stored for 2 weeks at 2°C.

<table>
<thead>
<tr>
<th>Storage treatments</th>
<th>Vase-life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not stored</td>
<td>13.3 c</td>
</tr>
<tr>
<td>Wet</td>
<td>7.8 ab</td>
</tr>
<tr>
<td>Wet + iprodione</td>
<td>11.3 bc</td>
</tr>
<tr>
<td>Dry</td>
<td>4.0 a</td>
</tr>
<tr>
<td>Dry + iprodione</td>
<td>13.2 c</td>
</tr>
</tbody>
</table>

*Mean separation by LSD (P < 0.05) = 4.7 days; NS = no significant differences (replication 6-fold).

Fig. 4. (A) Flower [LSD (P < 0.05) = 3.1 days, replication 6-fold] and foliage life [LSD (P < 0.05) = 1.5 days] of Geraldton wax held in 200 mg-liter⁻¹ HQS with an increasing series of sucrose concentrations from 0% to 20% (w/v). and (B) Flower [LSD (P < 0.05) = 2.6 days, replication 6-fold] and foliage life [LSD (P < 0.05) = 3.7 days] in a repeat experiment. Vertical bars indicate SD.

Discussion

The effects of wet and dry storage, with and without dipping in iprodione, were evaluated after storage for 2 weeks at 2°C. There was no significant (P < 0.05) difference in Geraldton wax vase-life between wet (stems in 200 mg-liter⁻¹ HQS) and dry (polyethylene wrap) storage (Table 4). However, iprodione treatment prior to storage greatly improved the vase-life of Geraldton wax (Table 4).

Preservative solution. Increasing the sucrose content of the floral preservative from 0% to 20% (w/v) resulted in somewhat inconsistent effects in different experiments. Increasing the sucrose level to 5% increased the flower vase-life. Beyond 5% sucrose, a general trend for reduced flower vase-life was observed in some experiments (e.g., Fig. 4A), whereas in others 10% sucrose gave an equally long (e.g., Fig. 4B) or even longer (data not shown) flower vase-life. Twenty percent sucrose was consistently associated with a reduced vase-life in comparison with lower sugar levels in the preservation solution. Secretion of nectar from floral nectaries was associated with high sucrose concentrations. The volume increased with increasing sucrose content of the preservative solution, being copious at sucrose levels of 5% and above. Foliage was generally more sensitive to sucrose injury than flowers (Fig. 4), the maximum safe level varying between 1% and 5% in different experiments. Foliage desiccated as a result of phytotoxicity.

Cold storage of Geraldton wax was beneficial, and substantially reduced respiration rates. The crop did not appear sensitive to chilling; dry storage for at least 2 weeks at 0°C appears feasible. Longer storage under optimum conditions of temperature and relative humidity could be anticipated. However, a...
Ripening of Mature-green Tomato Fruit Slices

Fabio Mencarelli1 and Mikal E. Saltveit, Jr.
Department of Vegetable Crops, University of California, Davis, CA 95616

Additional index words. Lycopersicon esculentum, respiration, C2H4, CA, climacteric, wounding, seed germination

Abstract. Equatorial 7-mm-thick slices of mature-green tomato fruit (Lycopersicon esculentum, Mill., cv. Castlemart) ripened normally, and changes in the concentrations of lycopene, soluble solids content, and titratable acids and in pH were analogous to, although in some cases significantly different from, changes in whole fruit that were harvested when mature-green and ripened. An untrained taste panel scored ripened slices acceptable to good, and no off-flavors were detected. Slices of mature-green tomato fruit can be ripened to an acceptable level of quality, and could provide an additional outlet for fresh-market tomatoes to the home and institutional markets.

Fresh vegetables are increasingly being sold in a “lightly processed” form (i.e., cut or shredded after harvest). Examples include shredded lettuce, and cut carrot and celery sticks. Cutting and shredding during preparation are some of the many types of wounds and stresses that induce altered physiological responses in tissue (7). These responses include increased CO2 and C2H4 production, accelerated ripening, senescence and water loss, and production of new, wound-induced chemicals. Several physiological and biochemical studies have been reported on excised tomato tissue (3, 4, 8, 10), but, to the best of our knowledge, no work has been published on the postharvest behavior of sliced tomatoes in relation to their quality and marketability as a fresh vegetable.

An increasing share of fresh tomatoes are used by the food service industry in salads and as garnishes. Marketing slices would eliminate trimming waste, and could provide an additional outlet for fresh-market tomatoes. In this paper we report on the effect of slicing on the ripening behavior of slices of mature-green tomato fruit.

Materials and Methods

‘Castlemart’ tomatoes were grown in the field according to normal cultural practices. Fruit were harvested mature-green and used the same day. Unblemished, uniformly shaped fruit with a mean fresh weight of 170 g were washed in a 1% sodium hypochlorite solution (20% commercial bleach), rinsed with sterile, deionized water, and surface-sterilized with 70% ethanol for 1 min at 20°C. All subsequent procedures were carried out under aseptic conditions. Three to four slices (each 7 mm thick) were cut from the equatorial region of the fruit with a stainless steel knife. The stage of maturity of each fruit was ascertained from an examination of the slices. Slices were separated into four classes: M1 (immature—firm locular tissue, seeds cut with knife); M2 (mature—softened locular tissue, seeds not cut with knife); M3 (mature—some gel in locule, no red

1 Received for publication 21 Sept. 1987. Supported by grant #SAL-9-070 from the California Fresh Market Tomato Advisory Board. Research partially supported by CNR, Italy. Special grant IPRA, subproject 3, paper No. 1401. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

2 Visiting scientist from Università degli studi della Tuscia, Istituto Tecnologie Agrarie & Microbiologia, 01100 Viterbo, Italy.

1. Blackall, W.E. and B.J. Grieve. 1980. How to know Western Australian wildflowers, part IIIA. Univ. of Western Australia Press, Nedlands, W.A.