Postharvest characteristics of cut *Camellia japonica* L. ‘Kumasaka’

Motoaki Doi *,1, Michael S. Reid

Department of Environmental Horticulture, University of California, Davis, CA 95616, USA

Accepted 21 August 1995

Abstract

Open flowers of cut *Camellia japonica* L. ‘Kumasaka’ placed in deionized water at 20°C and 60% RH wilted after only two days; unopened flower buds lasted longer under these conditions, but failed to open. When open flowers were placed at high humidity, the vase life was four days, and was terminated by petal abscission. Petal wilting resulted from the failure of the cut stem to replace water lost mainly through the flower petals, and was associated with a fall in water potential, reduced fresh weight, and reduced xylem conductivity. Flower abscission was preceded by petal browning and necrosis and these symptoms occurred concomitant with the development of a sharp rise in ethylene production. Treatment of cut flowers with 0.2 mM silver thiosulfate for 24 h prevented flower abscission, but did not delay the occurrence of necrotic brown spots.

*Keywords: Camellia japonica; Cut branch; Petal wilting; Flower abscission; Water relation; Ethylene production*

1. Introduction

*Camellia japonica* L. is an important ornamental shrub used as a potted plant and in landscape plantings. Camellia flowers attached on the plants last for seven–ten days, and flower senescence is characterized by the appearance of brown regions on the petals, followed by abscission of floral organs. In contrast, when camellia flowers are removed from the plant, they typically wilt rapidly unless held at low temperatures and high humidity (Bonner and Honda, 1950). The use of these flowers in the cut flower trade has therefore been restricted to situations where longevity is not especially important. Most authorities suggest harvesting the flowers with little or no stem, and holding them at high humidity (Threlkeld, 1962).

*Corresponding author. Fax: +81 (72) 252-0341.

1 On leave from: College of Agriculture, University of Osaka Prefecture, Sakai Osaka, 593, Japan.
It appears that poor water relations lead to early wilting of cut camellia blooms, and a considerable effort was made in the 1950's to find a treatment that would extend their short life (Cothran, 1958). Most of the effort was directed towards reducing vapor pressure deficit or preventing water loss from the petals. In recent years, researchers working with cut roses have noted the importance of maintaining stem hydraulic conductivity in preventing wilting (Van Doorn et al., 1989). The use of bactericides to prevent bacterial occlusion of xylem vessels (Van Doorn et al., 1991), and of wetting agents to overcome emboli (Jones et al., 1993; Van Doorn et al., 1993) are now standard practice. The possible value of such treatments in improving the life of cut camellia blooms has not been explored.

Woolf et al. (1992) reported that abscission of camellia flower buds was induced by a foliar spray with 2–4 ml l⁻¹ ethephon [(2-chloroethyl)phosphonic acid] and that the vegetative buds and leaves were less sensitive to ethephon than flower buds. This suggests the involvement of endogenous ethylene in naturally occurring camellia flower abscission and the possibility of silver thiosulfate (STS) being effective in preventing flower abscission.

The objectives of this study were to investigate the water relations of cut camellia flowers, the possible use of treatments designed to improve water relations, and to assess the role of ethylene in the abscission of camellia flowers and floral organs.

2. Materials and methods

Plant materials

Potted plants of *C. japonica* L. ‘Kumasaka’ were grown in a lath house at University of California, Davis, Calif. Cut flowers were harvested from these plants during the natural flowering time (from late February to early March). Unless otherwise noted, 6-cm softwood stems with three leaves and one flower or flower bud were used in four replications for each treatment. Flowers were harvested at different maturities: tight bud — showing color at the bud tip; petals elongating — calyx starting to open, ca. 10 mm of petals visible; swollen — calyx open, petals ca. 20 mm visible; just open — outer petals reflexed; two-day old — two days after opening; four-day old — four days after opening; six-day old — six days after opening.

Evaluation of cut flower longevity

Stem bases of harvested flowers were recut under water and held in glass vials containing 20 ml deionized (DI) water (pH adjusted to 5.0 with 1 mM citric acid/sodium citrate buffer) or vase solutions in a controlled environment cabinet at 20°C and ca. 60% relative humidity (RH) with 12 h lighting provided by cool-white fluorescent tubes (PAR at flower height ca. 10 mol m⁻² s⁻¹). Biocides and surfactants tested were 200 mg l⁻¹ 8-hydroxyquinoline citrate, 50 mg l⁻¹ sodium hypochlorite, 200 mg l⁻¹ Physan®, 300 mg l⁻¹ citric acid, and 100 mg l⁻¹ nonylphenol polyglycol ether. Addition of 20 g l⁻¹ sucrose in combination with these biocides was also tested. Flower life was considered terminated when necrotic brown regions appeared on petals or when petal wilting and/or abscission occurred.

To examine the effects of STS, cut flowers at the just open stage were rehydrated
with DI water or with a 0.2 mM STS solution for 24 h, and then placed in DI water. They were held at ca. 60% or nearly 100% RH.

**Effects of ethylene**

Cut branches with newly open flowers were rehydrated with DI water or pre-treated with a 0.2 mM STS solution for 24 h, and then placed in a tank ventilated (30 l h⁻¹) with air, or air containing 0.3 l⁻¹ ethylene.

To determine the ethylene production by flowering branches, stems with one leaf and one flower bud were harvested at different maturities. Four replicate flowering stems for each stage were placed in glass vials containing 15 ml DI water. Each of these vials was placed in a 500-ml glass vessel and the vessels were placed in a tank ventilated with humidified air. The vessels were sealed each day for 1 h, and ethylene production by the flowering stem was determined from the accumulation of ethylene in the headspace. Ethylene concentrations were measured using a gas chromatograph (Model 111, Carle Instruments, Inc., Anaheim, Calif.) fitted with a photoionization detector (Model PI-51, Hnu Systems, Inc., Newton, Miss.). Ethylene production by the vegetative portions of the cut flowers was negligible throughout the postharvest period (data not shown).

Ethylene production by six replicate individual petals was determined by sealing them in 20-ml glass vials for 1 h, withdrawing gas samples from the headspace and determining their ethylene content.

**Water relations**

Cut flowers harvested when just open were pulsed with 0.2 mM STS solution for 24 h to prevent flower abscission and then placed in DI water. Half of the flowers were placed in a room at ca. 60% RH (low RH). The other half were held in the same room, but in tanks ventilated (30 l h⁻¹) with humidified air. The RH around the cut flowers was phychrometrically measured at nearly 100% (high RH). Four replicates of the uppermost leaves were excised from replicate cut flowers at intervals and their water potential was determined immediately using a Scholander pressure chamber. The hydraulic conductance of the basal 5 cm of flowering stems was measured in four replications at harvest and after four days in the vase as described by Van Doorn et al. (1989).

To evaluate the contribution of leaves and flowers to water uptake and transpiration, water relations parameters were measured on four replicate branches placed in solution intact, or after removing the flower or the leaves. Water uptake and transpiration were calculated by periodically weighing cut branches and vase solutions. Initial fresh weight was transformed to 3 g for branches only with leaves, 15 g for those only with a flower, and to 18 g for those with both.

**Data analysis**

Experiments usually used four replicate flowers for each treatment. They were repeated at least twice using ‘Kumasaka’, and also repeated using ‘Elaenoea McCowan’. Since similar results were obtained in these experiments, data on a series of experiments using ‘Kumasaka’ were represented. Data were subjected to analysis
of variance and means were separated by Student’s t-test \((P = 0.05)\) or Duncan’s multiple range test \((P = 0.05)\).

3. Results

**Longevity of cut flowering branches**

Cut camellia flowers harvested when just open and held in DI water in a room with ca. 60% RH lost turgor within two–three days and then abscised (Table 1). Necrotic brown spots were observed on most abscised petals and stamens. Abscission occurred at the base of receptacles, calyxes, corollas and androecia in newly open flowers; the receptacle and ovary remained after abscission of corollas in flowers that were two- and four-day old at harvest. Flowers harvested at the tight-bud stage lasted for more than 15 days, but never opened. Even ‘swollen’ buds did not open completely.

None of a range of biocides and wetting agents tested (8-hydroxyquinoline citrate, sodium hypochlorite, Physan®, citric acid, and nonylphenolpolyglycol ether) improved the longevity of newly open flowers (data not shown). Addition of \(20 \text{ g l}^{-1}\) sucrose to these solutions was also without significant benefit.

Pulsing cut camellia flowers with STS prevented the abscission of floral organs (Table 2), although the STS treatment delayed neither petal wilting nor petal browning. Newly open flowers pulsed with STS and held under high RH conditions had the longest vase life of all flowers tested (five days).

**Water relations**

**Effects of RH:** The petals of harvested flowers did not lose turgor when they were held at high RH conditions (Table 2). However, neither the appearance of brown regions on the petals and stamens, nor petal abscission were inhibited by high RH.

### Table 1

Cut flower longevity of *C. japonica* ‘Kumasaka’ harvested at different maturities

<table>
<thead>
<tr>
<th>Harvest maturity</th>
<th>Flower bud opening (%)</th>
<th>Cut flower longevity &lt;sup&gt;a&lt;/sup&gt; (days)</th>
<th>Flower abscission (%)</th>
<th>Abscised organs&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tight buds</td>
<td>0</td>
<td>(&gt;15.0)</td>
<td>0</td>
<td>(-)</td>
</tr>
<tr>
<td>Petals elongating</td>
<td>0</td>
<td>7.0 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>100</td>
<td>R, Ca</td>
</tr>
<tr>
<td>Swollen</td>
<td>50</td>
<td>3.0 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>100</td>
<td>R, Ca, (Co, A)</td>
</tr>
<tr>
<td>Just open</td>
<td>(-)</td>
<td>2.5 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>100</td>
<td>(R), Ca, Co, A</td>
</tr>
<tr>
<td>Two-day old</td>
<td>(-)</td>
<td>2.3 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>100</td>
<td>Ca, Co, A</td>
</tr>
<tr>
<td>Four-day old</td>
<td>(-)</td>
<td>1.7 &lt;sup&gt;d&lt;/sup&gt;</td>
<td>100</td>
<td>Ca, Co, A</td>
</tr>
</tbody>
</table>

Cut flowers were held in DI water and placed at 20°C and ca. 60% RH with 12 h lighting.

<sup>a</sup> Regardless of the harvest maturity, flower life was terminated by petal wilting which occurred prior to flower abscission.

<sup>b</sup> Abscission occurred at the base of the following organs: R = receptacle; Ca = calyx; Co = corolla; A = androecium. Organs in parentheses abscised occasionally.

<sup>c</sup> Significant differences \((P = 0.05)\) are indicated by different letters.
Table 2
Effects of RH and STS pulsing on the senescing process and cut flower longevity of *C. japonica* 'Kumasaka'

<table>
<thead>
<tr>
<th>RH</th>
<th>Pulsing with STS</th>
<th>Cut flower longevity (days)</th>
<th>Flower abscission (%)</th>
<th>Senescing process a</th>
</tr>
</thead>
<tbody>
<tr>
<td>ca. 60%</td>
<td>No</td>
<td>2.8 a b</td>
<td>100</td>
<td>PW, then (PB), FA</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>2.5 a</td>
<td>0</td>
<td>PW, then PB</td>
</tr>
<tr>
<td>Nearly 100%</td>
<td>No</td>
<td>4.0 ab</td>
<td>100</td>
<td>(PB), then FA</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>5.0 b</td>
<td>0</td>
<td>PB</td>
</tr>
</tbody>
</table>

Cut flowers were harvested at the just open stage, rehydrated with DI water or with a 0.2 mM STS solution for 24 h, and then placed in DI water.

*a* Senescing process: PW = petal wilting; PB = petal browning; FA = flower abscission. Process in parentheses occurred occasionally.

b Significant differences (*P* = 0.05) are indicated by different letters.

Fig. 1. Water relations of intact, defoliated or deflowered cut branches of *C. japonica* 'Kumasaka' placed at ca. 60% RH (low RH) or at nearly 100% RH (high RH). Results are means of four replications and ±SE.
Table 3
Hydraulic conductance of 5-cm softwood stems of *C. japonica* 'Kumasaka' held under different RH conditions

<table>
<thead>
<tr>
<th>Time of measurement and holding RH</th>
<th>Hydraulic conductance (ml h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>0.67 a</td>
</tr>
<tr>
<td>Day 4, ca. 60% RH</td>
<td>0.27 b</td>
</tr>
<tr>
<td>Day 4, nearly 100% RH</td>
<td>0.29 b</td>
</tr>
</tbody>
</table>

Cut flowers trimmed to 6 cm were placed in DI water and basal 5 cm of stems were excised for measurement.

a Significant differences (*P* = 0.05) are indicated by different letters.

*Fresh weight:* After an initial slight increase, branches with flowers and leaves, or with flowers alone, lost fresh weight during the four days they were held at ca. 60% RH (Fig. 1a). In replicate stems held at high humidity, fresh weight increased more (ca. 2 g stem⁻¹) during the first day and was maintained thereafter. Stems of which the flower had been removed had a low weight, which remained constant throughout the experimental period.

*Water uptake:* A sharp decline in water uptake by stems was observed between days 1 and 2 in all treatments where the flower was left on them (Fig. 1b). By three days after harvest, water uptake by these stems was the same as in stems lacking flowers. Water uptake by stems of which the flower had been removed remained steady throughout the experiment, although much higher at 60% RH than at near saturation.

*Transpiration:* The presence of the flower on the stem substantially increased the rate and variability of water loss (Fig. 1c). Transpiration of replicate stems with the flower removed remained essentially unchanged throughout the experimental period. At high humidities, transpiration was extremely low and there was little difference between treatments.

*Hydraulic conductance:* Four days after harvest, the hydraulic conductance of stem segments was ca. one-third of that in freshly harvested stems, regardless of the humidity at which the flowers were held (Table 3).

*Water potential:* For the uppermost leaves of newly-harvested branches, the water potential (ϕ) was -0.2 MPa (Fig. 2). In flowers held at high RH, water potential remained relatively constant over the four-day period. Holding flowers at ca. 60% RH caused a sharp decrease in water potential between one and two days after harvest.

*Ethylene and flower abscission*

Newly open flowers placed in air abscised 4.5 days after harvest (Table 4). Exposure to 0.3 μl l⁻¹ ethylene accelerated the abscission process, which occurred two days after harvest. Pulsing cut flowers with STS prevented this ethylene-stimulated flower abscission.

Regardless of the maturity of flower buds at harvest, the initial rate of ethylene production by flowering stems was low (Fig. 3). A rise in ethylene production was
Fig. 2. Effects of holding RH on the leaf water potential of cut C. japonica 'Kumasaka'. Cut flowers were pulsed with 0.2 mM STS for 24 h and then placed in DI water. They were held at ca. 60% RH (low RH) or at nearly 100% RH (high RH). Results are means of four replications and ±SE.

Table 4
Effects of exogenous ethylene on the flower abscission of C. japonica 'Kumasaka' rehydrated with DI water or with a 0.2 mM STS solution for 24 h

<table>
<thead>
<tr>
<th>Exposure to ethylene</th>
<th>Pulsing with STS</th>
<th>Flower abscission (%)</th>
<th>Days to flower abscission</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>100</td>
<td>4.5 a*</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>100</td>
<td>2.0 b</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

Cut flowers were harvested at the just open stage, rehydrated with DI water or with a 0.2 mM STS solution for 24 h, and then placed in DI water. They were exposed to air or air containing 0.3 \( \mu l^{-1} \) ethylene.

* Significant differences \( (P = 0.05) \) are indicated by different letters.

detected prior to flower abscission. The time to this increase in ethylene synthesis decreased with advancing harvest maturity. The appearance of brown regions on the petals was closely associated with the increase in ethylene production by the flowers.

The rate of ethylene production by individual petals from newly open flowers was low (Table 5). In petals obtained from senescing flowers, the rate of ethylene production by petals with brown spots was six-fold that of petals lacking them.

4. Discussion

The premature wilting of harvested C. japonica flowers clearly results from poor water relations. The presence of the flower on the stem greatly increases the water requirements of the cut branch, as can easily be seen by the high water uptake during the first day in the vase (Fig. 1b). Since there are no functional stomata on camellia petals (unpublished data), water loss from petals is through the cuticle;
presumably, water loss from the leaves is mainly through stomata. For normal branches at low humidity conditions, the total water uptake (ca. 3 g) is partitioned between transpiration (2 g) and increased flower fresh weight (1 g). When similar branches were placed at high humidity, water uptake was similar (ca. 2.5 g), but was now partitioned differently, with 2 g going to increasing flower weight, and only 1 g lost in transpiration. These data indicate that in the very first day of postharvest life, the flower is unable to acquire sufficient water from the vase solution to supply the needs of petal expansion and transpiration. The result of this deficit is seen in water potential, which, two days after harvest, has already fallen to −0.6 MPa in flowers held at low humidity conditions. Curiously, when the leaves were removed, thereby reducing the rate of transpiration by the stem to about the same as that of the leaves alone (Fig. 1b), the flower still wilted under low humidity conditions. We are unable to explain this phenomenon which warrants further exploration.
The hydraulic imbalance in normal camellia stems is probably aggravated by a decrease in the hydraulic conductivity of the stem (Table 3), so that during the postharvest period the ability of the flower to draw water from the solution is increasingly impaired. In cut roses poor water relations and flower wilting has been related to reduced xylem conductivity, resulting from bacterial occlusions (Van Doorn et al., 1989), which may be followed by emboli (De Stigter and Broekhuysen, 1989). It does not appear that camellias are analogous to roses. Although we always recut stems under water to remove emboli, and tested a range of surfactants and biocides to inhibit vascular occlusion, none had any beneficial effect. Similarly, defoliation, which, as well as holding in high RH conditions, extended vase life by reducing water loss in roses (Carpenter and Rasmussen, 1974), but had no effect in camellias.

The facts that water relations are the key to the short vase life of camellias, and that none of the common remedies for poor water relations are effective in these flowers could explain the practical recommendation for the postharvest handling of camellias. Cothran (1958), for example, recommends holding flowers at low temperature and in sealed packages to ensure high RH, and even misting the petals to extend flower life.

Under high humidity conditions, where water relations are satisfactory, petal abscission, rather than water stress, terminates the vase life of camellia branches. A rise in ethylene production by individual flowers prior to petal abscission, the acceleration of petal abscission by exogenous ethylene, and effects of pulsing treatment with STS indicate that this process is regulated by endogenous ethylene. Pulsing cut camellias with STS provides a possible commercial means to prevent petal abscission. The STS treatment was of no benefit when applied to cut flowers harvested four–six days after bud opening (data not shown), suggesting that endogenous ethylene had triggered the abscission process before the flowers were harvested.

Increased ethylene production in camellia flowers was associated with necrotic browning of petals and stamens (Table 5). It has been reported that browning of the base of camellia petals may be caused by camellia flower blight (Ciborinia camelliae Kohn) (Baxter et al., 1987; Bennett, 1991). It is unknown whether the necrotic brown spots observed in our experiments were caused physiologically or pathologically. The close correlation between ethylene levels and abscission suggests that ethylene, whether or not from necrotic tissue, is the cause of petal abscission.

Our studies have not revealed a solution to the difficult problem of overcoming the poor water relations of harvested camellia flowers. Basic comparisons of water movement in intact and harvested stems might be used to further investigate this problem.

Acknowledgement

The authors wish to thank Linda Dodge for her expert technical support.

References