

# Effect of Vase Water Temperature and Leaf Number on Water Relations and Senescence of Cut Roses

Byung-Chun In, Myoung-Kap Chang, Hye-Jin Byoun, and Ki-Cheol Son\*

*Department of Environmental Science, Konkuk University, Seoul 143-701, Korea*

**Abstract.** The effect of vase water temperature and leaf number on water relations and senescence responses was determined in cut roses. Freshly harvested 'Red Sandra' roses were re-trimmed to 50 cm leaving two or four upper leaves and held in one of three solutions: ambient temperature distilled water (23°C; AT-DW), low temperature distilled water (7°C; LT-DW) and low temperature preservative solution (LT-PW). Flowers were kept in an environmental controlled room. Treatment effects evaluated were vase life, flower diameter, and changes in fresh weight and water uptake. Differences in water relations were determined by measuring CO<sub>2</sub> assimilation, stomatal conductance, and stem water flux rate (SFR). The water uptake rate was significantly increased in roses in LT-DW and decreased in those in LT-PW. While showing lower solution uptake rate during vase period, roses in LT-PW exhibited greatest fresh weight, longest positive water balance duration and largest flower diameter. Flowers with two leaves attached exhibited a higher fresh weight and improved water balance, thereby extending vase life. CO<sub>2</sub> assimilation rate and stomatal conductance were significantly decreased by placing flowers in LT-PW, yet increased by reducing leaf number to two leaves on the flower stems. Compared to the upper stem, the SFR of the basal stem of roses in AT-DW was lower, whereas SFR in basal stems of roses in LT-DW was much higher, suggesting that low-temperature water improved the hydraulic conductance in the stems. In contrast, roses in LT-PW had a stable SFR during the experimental period and displayed a similar pattern in SFR between upper and basal portions of the stems. Consequently, the vase life of cut roses in LT-PW and LT-DW was extended by more than eight and four days, respectively, compared to those in AT-DW.

**Additional key words:** photosynthesis, phyto-monitoring system, stem water flux, stomatal conductance, vase life

## Introduction

Cut roses often end their postharvest life at an early stage of maturation due to wilting, bent neck, blueing or abscission of flowers or leaves rather than undergoing the full natural senescence process that they manifest as intact flowers (Burdett, 1970; De Stigter, 1980; Zieslin, 1989). These manifestations of deterioration result from the complex interaction of a myriad of physiological process occurring in the flowers, leaves and stems that comprise each floral unit.

Water stress is the most common cause of shortening vase life for cut roses, not only because of their large leaf area and subsequent dense stomata (Ferreira and De Swardt, 1981; Mayak and Halevy, 1980), but also because of stomatal malfunctioning in roses grown under high relative humidity (RH) conditions (Mortensen and Gislerod, 2000; Torre et al.,

2003). It has also been demonstrated that most physiological and morphological factors affecting vase life of cut roses are closely related with the water status of flowers (In et al., 2007b, 2009b). The inherent longevity, i.e., potential vase life, of cut roses can be accurately predicted using these factors.

According to the gradient of water potential, water flows along a continuum from the vase water to the atmosphere through the stems, leaves and petals. Osmolytes, such as cations and soluble sugars, maintain the osmotic potential of petals by acting as the driving force of the water (Doi et al., 2000; Ichimura et al., 2003; Kuiper et al., 1995). Vascular occlusions are frequently developed gradually after harvest in the basal portion of the stems and ultimately reduce the rate of water uptake, which is often the primary reason for decrease in the hydraulic conductance of stems (Van

\*Corresponding author: kcsn@konkuk.ac.kr

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Doom, 1997; Van Doorn and Perik, 1990). Moreover, transpiration, which is regulated by stomata of the leaves, is a major cause of water loss from cut flowers (Carpenter and Rasmussen, 1974; Mayak et al., 1974). When transpiration is greater than water uptake, negative water balance accelerates flower senescence. Likewise, endogenous carbohydrates contained in leaves at harvest and photosynthetic activity after harvest also influence the water status of cut flowers in relation to transpiration (Doi et al., 2000; Evans and Reid, 1988; Son et al., 1997).

A number of studies have demonstrated positive effects of certain bactericides, surfactants, and energy sources (e.g., sucrose) on water absorption and vase life. Vase water temperature and the use of preservatives can also modulate the water relations of cut flowers. Several studies have shown that flowers kept in cold water (0-10°C) after a dry period increase water absorption relative to those placed in water at room temperature (Norikoshi et al., 2006; Slootweg, 1995; Van Meeteren, 1992), suggesting that cold water facilitates water flow in the stems.

In cut flowers the relationship between vase water temperature and water relations has not been adequately examined. We previously demonstrated that placing roses in low-temperature water resulted in an increased flux of water in the stems and reduced leaf boundary resistance, and with a preservative solution, significantly extended vase life. Here, we investigate the role of water temperature and number of leaves on water relations and senescence of cut roses. Furthermore, we discuss the interrelations between transpiration, photosynthesis, and internal water flux of cut roses according to number of leaves on stems.

## Materials and Methods

### Plant material

Flowers (*Rosa* spp. 'Red Sandra') harvested in the morning at appropriate maturity (onset of sepal reflex) were obtained from a commercial grower and transported under dry condition within 2 h to the laboratory. The stems of cut roses were re-cut under water to a length of 50 cm and contained either 2 or 4 upper leaves. These stemmed-flowers were placed in distilled water or preservative solution containing 200 mg·L<sup>-1</sup> 8-hydroxyquinoline sulfate (8-HQS) + 2% sucrose in a controlled environment room [23±0.5°C, 60±2% RH, light intensity of 20 µmol·m<sup>-2</sup>·sec<sup>-1</sup> (cool-white fluorescent tubes), 12 h photoperiod].

### Treatments

To examine the influence of different leaf area on water relations and photosynthesis of cut roses, cut flowers were

divided into two different groups based on the number of leaves retained on the stem: one group had two (two 3-leaflets; -2) and the other group had four (two 3-leaflets and two 5-leaflets; -4) upper leaves. Four roses of each group were placed each in a 1 L vase containing 800 mL of either: ambient-temperature distilled water (AT-DW); low-temperature distilled water (LT-DW); or low-temperature preservative solution (LT-PW). Low temperature (7±0.4°C) was maintained using a refrigerated vase (Maeil Engineering, Seoul, Korea), which was equipped with a semiconductor thermoelectric coolers (also known as Peltier coolers) to cool down the temperature of water in the vase. The other treatments were held in the same vases at ambient-temperature (22.8±0.3°C).

### Evaluations of vase life and senescence

The treatment effects were determined by measuring changes in water uptake, relative fresh weight (RFW), flower diameter, and vase life daily at 14:00. The amount of water taken up was corrected by subtracting evaporation of water from vases without cut flowers. Flower diameter was determined by measuring the widest diameter of each flower and the diameter perpendicular to it. Cut flowers were considered to have reached the end of their vase life when either wilting and blueing of petals or bending of neck occurred. All flowers showed withering or blueing before bending of neck in this study.

### Determinations of photosynthesis, stomatal conductance and stem water flux

CO<sub>2</sub> assimilation and stomatal conductance were measured using portable photosynthesis system (LI-6400; Li-COR, Lincoln, NE, USA) mounted onto a leaf chamber. The measurements were performed on terminal leaflets of uppermost leaves with three-leaflets twice every other day, both in the morning (2 h after the transition to light) and at night (2 h after the transition to dark). Changes in stem water flux rate (SFR) were measured daily morning and night using phyto-monitoring system (LPS-03; Phyttech, Rehovot, Israel). SFR sensors were fitted 1 cm below the peduncle and 15 cm above the stem end of flower stem.

### Experimental design and statistical analyses

The experiment followed a completely randomized design with six treatments, three replications for each treatment, and 4 flowers per replication. Data are presented as means ± standard errors. Data were subjected to one-way analysis of variance (ANOVA) using generalized linear model program of SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Means between groups were compared using the LSD test at *P* = 0.05. The entire experiment was replicated twice with no significant

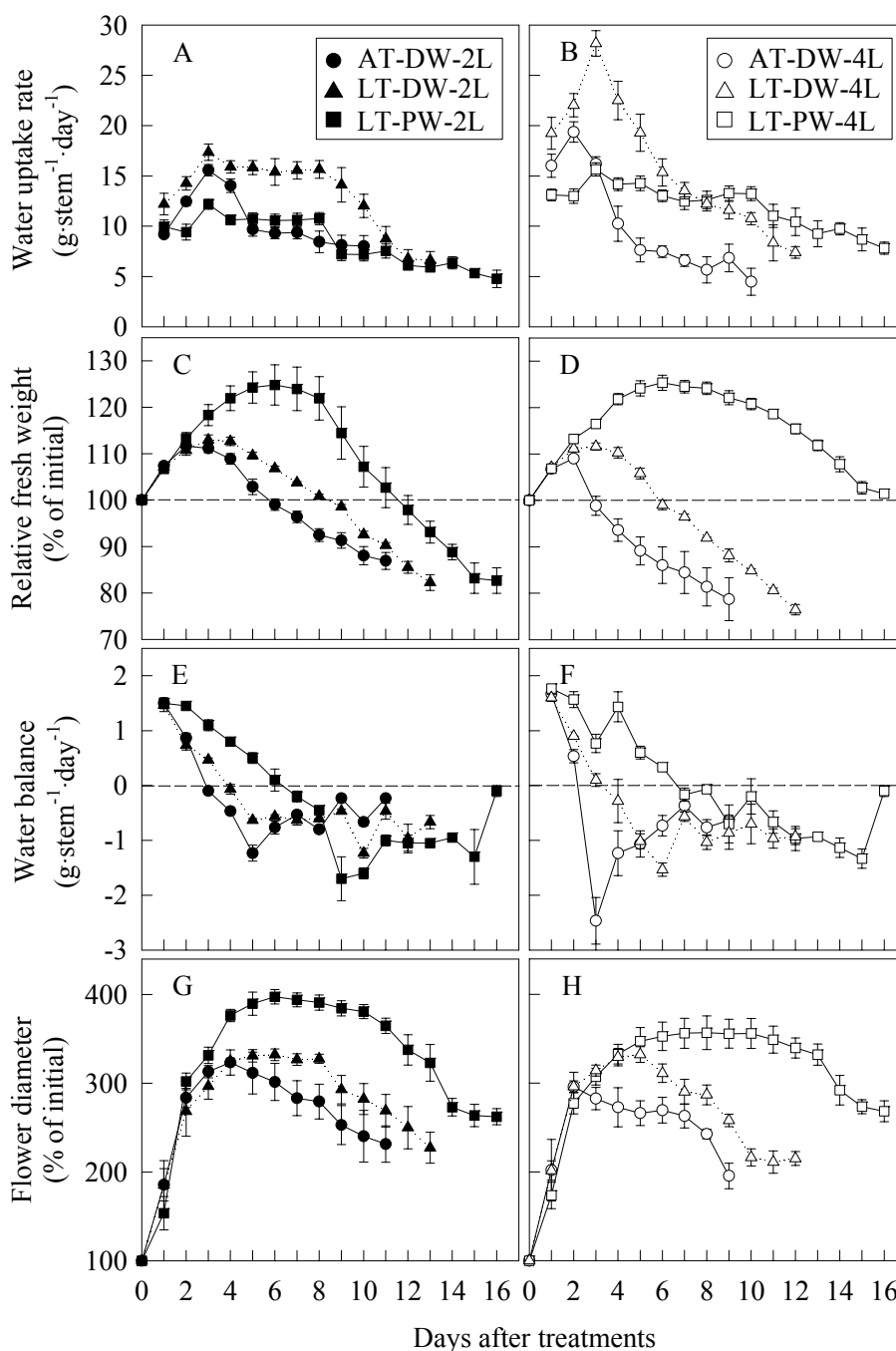
differences in patterns or degrees of response between replicates. To this end, data from only one experiment is reported.

## Results

### Physiological and quantitative changes over time

The initial water uptake was greater for flowers with 4 leaves compared to those with 2 leaves, and the onset of the decline in water uptake occurred earlier in these flowers

with the exception of the flowers in LT-PW (Fig. 1A and B). While the water uptake rate for AT-DW flowers with 2 and 4 leaves was lowest after 4 and 3 days, respectively, due to their rapid decline, the rate of water uptake for LT-DW flowers with both leaf numbers markedly increased and was subsequently maintained the highest during the experimental period. Water uptake for flowers in LT-PW exhibited a smaller increase initially, but was maintained steadily until the later stages.



**Fig. 1.** Effects of low-temperature water, preservative and leaf number on water uptake, relative fresh weight, water balance, and flower diameter of cut roses ('Red Sandra') with two (-2L) or four (-4L) leaves. AT-DW, ambient-temperature water; LT-DW, low-temperature water; and LT-PW, low-temperature preservative solution. Vertical bar indicates standard error ( $n = 3$ ).

Changes in RFW-measured as the percentage of initial weight of the flowers in AT-DW and LT-DW-reached a maximum at day 2 and 3, respectively, and subsequently decreased rapidly thereafter. In contrast, RFW of the flowers in LT-PW increased until day 6 and then gradually decreased (Fig. 1C and D). When flowers were held in AT-DW and LT-DW, the initial RFW was maintained longer in the flowers with 2 leaves than those with 4 leaves, whereas the pattern was reversed in the flowers in LT-PW. The RFW of the flowers with 4 leaves did not drop below the initial value.

Water uptake rate and RFW of flowers were reflected

**Table 1.** Effect of low-temperature water, preservative solution, and number of leaves on petal withering, petal blueing and bent neck of cut rose 'Red Sandra'.

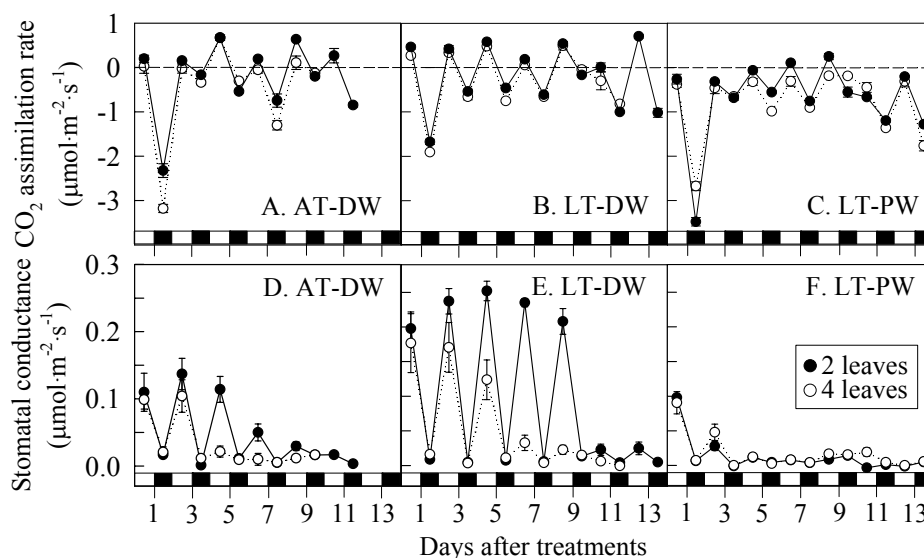
Treatment	Petal withering (days)	Petal blueing (days)	Bent neck (%)
AT-DW-2L	7.0 ± 0.41c	8.0 ± 0.41cd	75
AT-DW-4L	4.3 ± 0.33d	6.3 ± 0.33d	100
LT-DW-2L	11.0 ± 0.41b	8.7 ± 0.95bc	0
LT-DW-4L	8.5 ± 0.50c	9.0 ± 0.58b	50
LT-PW-2L	12.5 ± 0.96b	11.2 ± 0.48a	0
LT-PW-4L	15.5 ± 1.19a	12.7 ± 0.75a	0

AT-DW, Ambient-temperature water; LT-DW, Low-temperature water; LT-PW, Low-temperature preservative solution (200 mg·L<sup>-1</sup> 8-HQS + 2% sucrose). -2L, cut roses with 2 leaves; -4L, cut roses with 4 leaves. Degree of bent neck was measured on day 10. Data are presented as means ± SE (*n* = 3). Means with different letters (a-d) are significantly different at *P* = 0.05.

in water balance (Fig. 1E and F). For groups of plants with either two or four leaves, water balance was maintained longer in plants of the LT-PW treatment (6 days) compared to plants of AT-DW (2 days) or LT-DW (3 days) treatments. The onset of negative water balance was slightly faster in flowers with 4 leaves relative to those with 2 leaves when flowers were kept in AT-DW and LT-DW. This pattern, however, was reversed in LT-PW.

Changes in flower diameter-measured as the percentage of initial diameter-were similar to changes in RFW across all treatments. The increase in radial expansion of the flowers was notably higher for the flowers in LT-PW compared to those in AT-DW or LT-DW (Fig. 1G and H). The flower diameter was slightly larger in the flowers with 2 leaves than those with 4 leaves in all treatments.

The time period before flowers became unacceptable due to petal wilting was prolonged by about 4 and 8 days in LT-DW and LT-PW, respectively, relative to AT-DW. Likewise, petal bluing in LT-PW was delayed by more than 6 days compared to AT-DW (Table 1). By the 10th day of vase period in AT-DW, bent neck had occurred in 75% and 100% of the flowers with 2 and 4 leaves, respectively. Neck bending occurred neither for flowers held in LT-PW nor for those with 2 leaves held in LT-DW, but rather vase life eventually ended due to petal senescence or abscission. A longer vase life was observed for flowers with 2 leaves when flowers were placed in distilled water. Vase life was extended yet even further when 4 leaves remained on the stems and stems were placed in preservative solution.



**Fig. 2.** Changes in CO<sub>2</sub> assimilation rate and stomatal conductance of cut roses ('Red Sandra') with two (-2L) or four (-4L) leaves. Cut roses were maintained in AT-DW (ambient-temperature water), LT-DW (low-temperature water) and LT-PW (low-temperature preservative solution) under a 12-hr photoperiod. Bars indicate light (open bar) and dark (closed bar) periods. Vertical bar indicates standard error (*n* = 3).

### Changes in photosynthesis and stomatal conductance

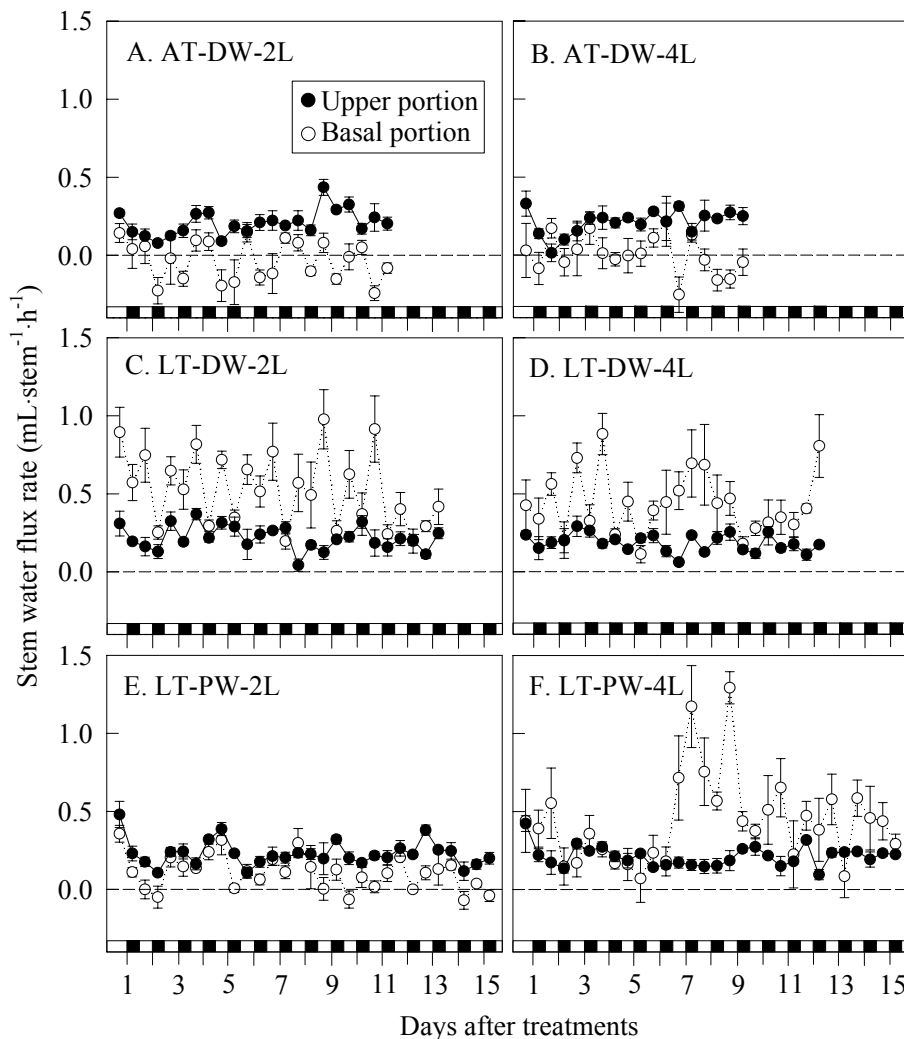
The rate of CO<sub>2</sub> assimilation and stomatal conductance were measured during morning (light) and night (dark) periods throughout the experiment. For all treatments, CO<sub>2</sub> assimilation rate of flowers initially showed a large decline; this decline was followed by diurnal fluctuations corresponding to the alternating light and dark periods (Fig. 2A-C). A consistent trend for all treatments was that flowers with 2 leaves exhibited slightly higher CO<sub>2</sub> assimilation compared to those with 4 leaves. When flowers were held in LT-PW, CO<sub>2</sub> assimilation was quite low compared with flowers held in AT-DW and LT-DW. Assimilation of LT-PW-treated flowers was negligible even during the day and onward throughout the experimental period (Fig. 2C). There was no clear difference observed in CO<sub>2</sub> assimilation rate between the flowers in AT-DW and LT-DW (Fig. 2A and B).

Stomatal conductance was initially higher and decreased

during the latter stages of the experiment (Fig. 2D-F). The flowers with 2 leaves also showed a higher stomatal conductance relative to those with 4 leaves during vase period. When flowers were held in LT-PW, no differences in stomatal conductance between the flowers with 2 and 4 leaves were observed (Fig. 2F). In other words, after a small but detectable increase in the initial stages, flowers in LT-PW did not transpire water to any measurable amounts. This is in sharp contrast to flowers in LT-DW, which showed the highest stomatal conductance (Fig. 2E).

### Change in stem water flux rate

SFR was measured at upper and basal portions of cut flower stems in the morning and at night (Fig. 3). Changes in SFR of upper portions exhibited similar patterns across all treatments, regardless of leaf number: SFR tended to decrease rapidly within the first 3 days, then remained fairly constant. In



**Fig. 3.** Changes in stem water flux rate of cut roses ('Red Sandra') with two (-2L) or four (-4L) leaves. Cut flowers were maintained in AT-DW (ambient-temperature water), LT-DW (low-temperature water) and LT-PW (low-temperature preservative) under a 12-hr photoperiod. Bars indicate light (open bar) and dark (closed bar) periods. Vertical bar indicates standard error ( $n = 3$ ).

contrast to both treatment groups and leaf numbers, the SFR of the basal portion showed quite different patterns. In flowers in AT-DW, SFR of the basal portion was lower than that of the upper portion and often decreased to negative levels, regardless of photoperiod (Fig. 3A and B). For flowers in LT-DW, however, SFR of the basal portion was significantly higher than that of the upper portion, and showed rhythmic changes in accordance with the light and dark alterations (Fig. 3C and D). This photoperiodic pattern was more pronounced in flowers with 2 leaves compared to those with 4 leaves. Conversely, for flowers in LT-PW, changes in SFR showed a similar pattern for both upper and basal portions of the stem (Fig. 3E and F); these changes persisted throughout the experimental period. In late stages of vase life, four-leafed flowers in LT-PW showed a spike in SFR of basal portion (Fig. 3F).

## Discussion

Because immediate post-harvest cellular water absorption and stem hydraulic conductance in cut flowers are high, water flux in the xylem is of a fast enough rate to meet the requirement for water. However, over time, as cell turgor decreases, tissue degradation inhibits water flow in the stem of cut flower, and a decrease in osmotic concentration results from a continuous respiratory activity in the petal that cannot compensate the water requirements of the flowers (Burdett, 1970; Carpenter and Rasmussen, 1973; Van Doorn, 1989).

During initial period when cut roses had the ability to absorb water efficiently, the water balance was maintained transiently (Fig. 1E and F) because water uptake by flowers was high enough to compensate for water loss by transpiration. As a result, the rate of water uptake for later-staged roses could not compensate for the lack of water to supply the demands for cell expansion or water loss by transpiration. Subsequently, a negative water balance resulted as hydraulic conductance declined over time.

We found a positive effect of low-temperature water in the vase for water absorption by cut roses. The flowers held in LT-DW exhibited higher water absorption and RFW, and subsequently improved water balance compared to those kept in AT-DW (Fig. 1A-F), indicating that low-temperature water has an important role in maintaining hydraulic conductance in the stem. Importantly, inclusion of preservative to low-temperature water in the vase significantly improved the water balance of cut roses despite their relatively low water uptake during early stages. The flowers kept in LT-PW maintained water balance, RFW and flower diameter relative to those in AT-DW and LT-DW (Fig. 1A-H). It has been demonstrated previously that cut roses held in preservative

solution retain water status because sucrose, present in the preservative, promotes stomatal closure, which inhibits water loss from leaves (De Stigter, 1980; Ichimura et al., 1999; Marousky, 1969; Son et al., 1997) while lowering the water absorption.

Moreover, in previous studies we also found that the cut roses kept in preservative solution at ambient-temperature (AT-PW) exhibited considerably lower water uptake, slower SFR and subsequently shorter vase life compared to those kept in LT-PW (In et al., 2009a). Low water absorption in cut roses in AT-PW occurred because sucrose-induced stomatal closure reduces the driving force. Whereas the water absorption by cut roses in LT-PW did not strikingly decrease even in the later stages, the water relations were improved (Fig. 1A and B). Consequently, vase life of cut roses in LT-PW was extended more than 8 and 4 days longer than those in AT-DW and LT-DW, respectively (Table 1). This suggests that LT-PW is better opted for maintaining water relations of cut roses because of the synergism between the preservative and cold water in inhibiting water loss and promoting more efficient absorption (Ichimura et al., 1999; In et al., 2009a; Van Meeteren, 1992).

When cut flowers were held in distilled water, the flowers with 4 leaves showed higher water uptake in the earlier stage than those with 2 leaves (Fig. 1A and B). However, the onset of negative water balance was faster in the flowers with 4 leaves due to excessive water loss from the larger leaf area (Fig. 1C and D). This may be the cause of developing earlier wilting and bent neck in the flowers with greater leaf numbers (Carpenter and Rasmussen, 1974; Ferreira and De Swardt, 1981; He et al., 2006). Consequently, vase life of flowers with 4 leaves was shortened by more than 2.5 days relative to that of the flowers with 2 leaves when they were held in distilled water (Table 1). However, an opposite trend was observed for flowers held in preservative solution. These data indicate water uptake was much higher in flowers with 4 leaves despite extremely low transpiration independent of leaf number. Thus, the initial RFW and water balance of the flowers with 4 leaves was maintained longer, which resulted in prolonging the vase life by more than 2.5 days relative to that of flowers with 2 leaves.

Leaves of cut flowers are more competitive sinks for water supply than flowers because internal water potential is higher in the flower than leaves (He et al., 2006; Hu et al., 1998; Song et al., 1992). Smaller flower diameter in the flowers with 4 leaves is likely caused by inadequate water flux into the petals that results from a competition for water between higher leaf number versus floral structure (Fig. 1G and H).

In cut rose flowers, CO<sub>2</sub> assimilation rate was very low even throughout the light period. There were no significant

differences between CO<sub>2</sub> assimilation rate of the flowers kept in ambient- and low-temperature water (Fig. 2A and B), despite measurable differences in change in stomatal conductance. Placing flowers in preservative solution significantly reduced CO<sub>2</sub> assimilation (Fig. 2C). A negative assimilation rate was maintained even during the light period, implying that the open stomatas are not required for flowers absorbing CO<sub>2</sub> for photosynthesis because sucrose in the vase solution is utilized by cut flowers as the carbon supply for respiration. We also observed suppression of stomatal conductance from the leaves of the flowers (Fig. 2F). In contrast, stems with lower leaf number increased CO<sub>2</sub> assimilation rate and stomatal conductance of cut flowers. In addition, cut flowers exhibited a highly negative CO<sub>2</sub> assimilation in the initial stage of vase period. This is likely due to negative CO<sub>2</sub> assimilation (e.g., respiration) resulting in increased respiratory activity for energy supply required during flower bud opening. In support of this hypothesis, we observed flower diameter greatly increased at that time (Fig. 1G and H) and there was a high flux of water into the flower stems (Fig. 3A-F). This driving force at the beginning of vase life correlated with the cellular water requirement at the onset of petal expansion in cut roses. Our interpretation is consistent with other reports explaining how water potential in flowers and leaves dramatically increases during this time of development and the removal of flowers from stem resulted in a decrease of the water uptake (Carpenter and Rasmussen, 1974; Doi et al., 1999; Hu et al., 1998; Van Doorn and Reid, 1995). Moreover, cut flowers maintain their metabolic functions by increasing photosynthetic and transpiration activities when they were placed in water without sucrose or with fewer number of leaves (Fig. 2A-F). Such phenomenon can be considered as homeostasis for normal processes in flower opening or recovery of the metabolic system under the circumstance where the flowers are detached from mother plants.

The SFR of basal portions of stems showed completely different patterns between treatments. A lower SFR at basal portions relative to upper portions of flowers in AT-DW (Fig. 3A and B) suggested that water absorption by stem ends is lower than water loss from flowers or leaves. This observed imbalance between water uptake and water loss led to a rapid negative water balance in the flowers. In contrast, the SFR of upper portions increased drastically when the flowers were held in LT-DW (Fig. 3C and D), indicating that low-temperature water improved the hydraulic conductance of flower stems. Subsequently, water balance of the flowers in LT-DW was improved over that of the flowers in AT-DW. SFR of the basal portion of flowers in LT-DW showed diurnal fluctuations corresponding to the light and dark periods. This implies that in LT-DW, the

promotion of water absorption in flowers is closely related with transpiration activity of leaves. Interestingly, flowers held in LT-PW exhibited a similar pattern in SFR between at upper and basal portions of the stems (Fig. 3E and F). Our data suggest that SFR of flowers in LT-PW is determined mainly by water requirement of cell throughout flower opening since flowers in LT-PW did not transpire to any significant degree during the vase period. Thus, this balance between water requirement and absorption significantly improved water status and thereby delayed senescence of the flowers. In LT-PW, the flowers with 4 leaves showed a sudden increase in SFR of basal portion in the later stage, which may have resulted from maintaining a high RFW until the end of vase life.

In cut roses, restrictions on water uptake are among the main factors in negative postharvest water relations (Reid et al., 1996). Air bubbles are often observed culprits of increasing hydraulic resistance in the stems (De Stigter, 1981; Van Doorn, 1989; Van Meeteren et al., 2006). Entrapped air bubbles in the xylem increase resistance to water flow, blocking water movement within the vessel element. This phenomenon (i.e. xylem cavitation) is most likely minimized by cold water, which can dissolve more gasses than water at room temperature, resulting in decreasing resistance to water flow (Slootweg, 1995; Van Meeteren, 1992; Van Meeteren et al., 2006). In addition, water flow in stems of cut flowers could also be influenced by levels of microorganisms (Marousky, 1969; Van Doorn, 1989; Zagory and Reid, 1986). Norikoshi et al. (2006) found that cold water in the vase suppressed the growth of bacteria during the vase period.

Previous studies by our group revealed that the patterns of water uptake of cut roses were completely different between water at room temperature and cold water despite containing the same germicide (In et al., 2009a). Moreover, the effect of low-temperature water for increasing of water uptake was observed most effectively at the early stage when the vase water is uncontaminated with bacteria. Likewise, the stem ends of all flowers were re-cut under water in order to prevent an airbubble in the stem in this study. Removal of air bubbles in the xylem and suppression of bacterial growth in the vase water do not explain wholly the effect of low-temperature water promoting absorption of water.

There are many other possible mechanisms explaining such a strong effect of low-temperature water on increasing water flow. First, when the water temperature is high, the water molecules vibrate, and the hydrogen bonding is loosened. In low temperature water, however, the hydrogen bonding would remain stable with a strong cohesion-tension (Taize and Zeiger, 1998), resulting in increased tensions in the xylem water column. Secondly, when cut roses absorbed cold

water, transpiration stream increases, perhaps due to reduced leaf boundary layer resistance (BLR) resulting from the generation of local convections around the leaf by temperature difference between leaf surface and air (Grace, 1988; Taize and Zeiger, 1998). This hypothesis is supported by our previous studies showing that leaf temperature and BLR dramatically decreased when cut roses were placed in cold water (In et al., 2007a, 2009a). Furthermore, the SFR of the upper portion of floral stem was not influenced, but that of basal portion markedly increased along with transpiration by holding flowers in cold water, implying that the driving force in water absorption is dependent on transpiration rate.

The current study reinforces the overall understanding of the water relations, by measuring not only the rehydration patterns of cut flowers but also the relations between photosynthesis, stomatal conductance, and water flux in the stem. The results obtained from this experiment suggest that cut roses kept in low-temperature water maintained water more efficiently and adding preservative to low-temperature water results in a synergistic effect in improving water relations and vase life of cut roses. Our data also revealed that cut roses with fewer leaves keep their metabolic activities through altering fluxes of photosynthesis and transpiration. Because cut roses are particularly vulnerable to post-harvest water stress, their ornamental value is often lost at florist shops or immediately after purchase by consumers. By incorporating data from this study, the consumer has a convenient, practical and effective method of prolonging vase life of cut roses through application of low-temperature water with preservative.

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## 절화장미의 수분관계와 노화에 대한 용기내 수온과 염수의 효과

인병천 · 장명갑 · 변혜진 · 손기철\*

건국대학교 생명환경과학대학 환경과학전공

(\*교신저자)

**초 록.** 절화 장미의 수분관계와 노화반응에 대한 용기내 수온과 염수의 효과를 조사하였다. 신선한 상태로 수확된 ‘Red Sandra’ 장미의 줄기는 상위엽 2매 또는 4매와 함께 길이 50cm로 정리되었다. 절화는 상온증류수(23°C; AT-DW), 저온증류수(7°C; LT-DW), 또는 저온보존용액(LT-PW)이 포함된 용기에 침지된 상태로 환경제어실에서 유지되었다. 처리간의 효과는 절화수명, 화경, 생체중 및 수분흡수량의 변화에 의하여 평가되었다. 수분관계에 있어서 차이는 CO<sub>2</sub>동화율, 기공전도, 그리고 줄기수분유속(SFR)을 측정함으로써 판단되었다. 수분흡수율은 LT-DW 장미에서 현저하게 증가되었고, LT-PW 장미에서 감소되었다. LT-PW 장미는 실험기간 동안 낮은 용액흡수량을 보였음에도 불구하고, 높은 생체중, 가장 긴 정의 수분균형기간, 그리고 가장 큰 화경을 나타냈다. 2매엽의 장미는 높은 생체중과 향상된 수분 균형을 유지한 결과로 절화수명이 연장되었다. CO<sub>2</sub>동화율과 기공전도도는 LT-PW에 유지함으로써 현저하게 감소되었고, 염수의 감소에 의하여 증가되었다. AT-DW장미의 경우, 줄기상부에 비하여 줄기하부의 SFR이 낮았으나, LT-DW 장미는 줄기하부의 SFR이 훨씬 컸다. 이것은 저온수가 줄기내의 수분전도율을 향상시킨다는 것을 나타낸다. 반면, LT-PW 장미는 실험기간 동안 안정된 SFR을 유지하였고, 줄기상부와 줄기하부에서 유사한 SFR 패턴을 나타냈다. 결과적으로 LT-PW와 LT-DW장미는 AT-DW 장미에 비하여 절화수명이 각각 8일과 4일 이상 연장되었다.

**추가 주요어 :** 광합성, 생체계측시스템, 줄기수분유속, 기공전도, 절화수명