Postharvest Handling of Stock (*Matthiola incana*)

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Abstract. The respiration of flowers of stock [*Matthiola incana* (L.) R. Br.] had a Q₁₀ of 6.9 between 0 and 10 °C. Simulated transport for 5 days resulted in marked reduction in the vase life of flowers transported at 10 °C and above. Flower opening, water uptake, and vase life of the flowers increased somewhat in a vase solution containing 50 ppm NaOCl, and considerably in a commercial preservative containing glucose and a bactericide. Exposure to exogenous ethylene resulted in rapid desiccation and abscission of the petals, effects that were prevented by pretreatment with 1-methylcyclopropene (1-MCP). Even in the absence of exogenous ethylene, the life of the flowers was significantly increased by inhibiting ethylene action using pretreatment with silver thiosulfate (STS) or 1-MCP. STS was more effective than 1-MCP in maintaining flower quality.

Long a staple crop in the florist trade, stock has become increasingly important in recent years, favored for its wide range of colors, interesting form, and intense fragrance. Postharvest problems include rapid wilting due to contamination of the vase solution, negatively gravitropic curvature, and response to ethylene. In 1975, Nowak and Rudnicki reported that a vase solution containing hydroxyquinoline sulfate (HQS), 0.005% CCC (chlormequat), and 5% sucrose (Proflovit) improved the life of stock flowers. More recently, Song et al. (1996) demonstrated improved vase life of stock flowers pretreated with STS, and when the flowers were held in a vase solution containing HQS as biocide and 1% sucrose. They also suggested reduced “tip curvature” and improved vase life in solutions containing low concentrations of calcium. Serek et al. (1995) found that 1-MCP, a gaseous inhibitor of ethylene action, prevented the deleterious effects of ethylene on stock flowers, but they did not compare 1-MCP with STS, nor evaluate its effects in the absence of ethylene. There has been no evaluation of the effect of NaOCl, a more effective general-spectrum biocide, on the vase life of stock.

The critical role of temperature in the life of cut flowers has long been cited in the literature and in texts on postharvest handling of these products (Carow, 1978; Hardenburg et al., 1986; Jones and Moody, 1993; Maxie et al., 1973; Nowak and Rudnicki, 1990; Sacalis, 1993). Current commercial practice in the United States for most cut flowers provides, at best, temperatures from 5 to 10 °C during the transportation period, which often lasts 4 to 5

d. The objective of the experiments reported here was to examine the roles of vase solution additives, anti-ethylene treatments, and storage temperature on the postharvest performance of stock.

Materials and Methods

Plant material. Flowers were purchased from a commercial supplier in California and transported directly to Davis after harvest for the experiments on vase solution additives, effects of exogenous ethylene, measurement of respiration at different temperatures and effects of storage temperature. Flowers were grown in the greenhouse of Atatürk Central Horticultural Research Institute in Yalova (Turkey) and harvested immediately before use for the experiments on the effect of different ethylene inhibitors on vase life.

Effect of vase solution additives. Six replicate flowers for each of the six treatments were recut to 35 cm, and placed in deionized water (DI) alone, or in DI with different additives; 1 mM Ca(NO₃)₂, 50 ppm NaOCl (chlorine bleach) alone or in combination with 1 mM Ca(NO₃)₂, or a commercial preservative containing glucose and a bactericide (Prsv-Crystal Clear; Floralife, Waltherboro, S.C.) alone or with 1 mM Ca(NO₃)₂.

Effect of inhibitors of ethylene action. Nine replicate flowers for each treatment (control, 1-MCP, and STS) were recut to 40 cm. Nine flowers were pulsed with 1 mM STS for 4 h at 20 °C. The flowers for control and 1-MCP treatments were placed in DI water. Flowers were sealed in a 40-L glass chamber for treatment with 1-MCP. Treatment was with a concentration of 500 nL·L⁻¹ for 6 h at 20 °C. After treatments, the flowers were recut to a stem length of 35 cm and placed in DI water in the controlled-environment vase life evaluation room at 20 °C and under artificial light of 12 h/day from cool-white fluorescent tubes.

Effects of ethylene and 1-MCP. After treatment with 500 nL·L⁻¹ 1-MCP or air (control)

for 6 h, six replicate flowers were sealed in a 40-L glass aquarium and exposed to a flowing stream (≈40 L·h⁻¹) of air containing 1 μL·L⁻¹ ethylene for 2 d. The flowers were then placed in the vase life evaluation room for periodic evaluation of the effects of the treatments.

Respiration measurement. The effect of temperature (ranging from 0 to 20 °C) on respiration was determined using the “dynamic” system described by Cevallos and Reid (2000), in which we followed respiration of individual flowers over the whole temperature range. One stock inflorescence was cut to 15 cm from the tip, placed in DI water, and sealed in a jar ventilated with a flowing stream of CO₂-free (obtained by passing air through a soda-lime column) air at a flow rate (≈4 L·h⁻¹) sufficient to prevent CO₂ concentrations from rising above 500 ppm at the highest temperature used (20 °C). The jar was submerged in a 30% glycol bath (LAUDA K-4/R; Brinkmann Instruments, Westbury, N.Y.) providing precise control of temperature. Respiration of the flower was determined by continuously recording the CO₂ concentration at the outlet of the jar using an infrared gas analyzer (Qubit Systems Inc., Kingston, Ont., Canada).

The flowers were held overnight at 20 °C in the respiration chamber to dissipate any effects of handling on respiration. The CO₂ concentration was recorded; then the temperature of the bath was changed to 15 °C. After a stable CO₂ reading was obtained (≈1.5 h), the temperature of the bath was further reduced to 12.5 °C and, after similar time intervals, to 10, 7.5, 5, 2.5, and 0 °C. The effect of temperature on respiration was measured in this manner for at least three replicate flowers that were held at 2 °C in DI water pending the respiration analysis.

Storage experiment. Replicate flowers were randomly assigned to groups (six flowers per group), wrapped in newsprint and polyethylene, and placed in fiberboard boxes at a range of storage temperatures (0 to 15 °C). After storage for 5 d, the flowers were recut to a stem length of 35 cm and placed in a commercial preservative containing glucose and a bactericide in the controlled-environment vase life evaluation room. The room was kept at 20 °C and ≈60% relative humidity. Artificial light (15 μmol·m⁻²·s⁻¹ photosynthetically active radiation) was provided for 12 h/day from cool-white fluorescent tubes (Sylvania Lighting Co., Danvers, Mass.).

Determination of vase life. The flowers were examined daily and their fresh weight, and/or the number of buds and open and dead flowers were determined. Vase life was considered to be terminated when half of the open florets were wilted or when flowers had returned to their initial fresh weight.

Statistical analysis. Data were statistically analyzed using one-way analysis of variance and Tukey’s multiple comparison test. Respiration data were subjected to regression analysis.

Results

Effect of vase solution additives. The vase life of stock flowers was significantly (*P* <

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0.05) increased when the flowers were held in a solution containing 50 ppm NaOCl (Table 1), and particularly when they were placed in a commercial preservative containing glucose and a bactericide. Compared to those held in DI water, flowers lasted 1.6 d longer in NaOCl, and 6 d longer in the commercial preservative solution. The addition of $\text{Ca}(\text{NO}_3)_2$ to these solutions did not improve postharvest performance. Opening of the nine to 10 florets on each spike was significantly improved only in the commercial preservative solution containing glucose (Table 1); while 97% of the florets had opened in the preservative solution after 10 d in the vase, only 67% had opened on spikes held in DI water. The effects of the vase solution components on vase life were mirrored in the pattern of change in the fresh weight of flowers (Fig. 1). Flowers returned to their initial fresh weights after ≈ 5 d in DI water and 7 d in NaOCl. Flowers in preservative solution remained above their initial fresh weight more than 9 d. The addition of $\text{Ca}(\text{NO}_3)_2$ to the vase solution had no effect on changes in flower weight, apart from a slightly negative effect for flowers held in the commercial preservative solution.

Effect of 1-MCP on ethylene mediated abscission of florets. Exposure of stock flowers to $1 \mu\text{L}\cdot\text{L}^{-1}$ ethylene for 2 d resulted in 100% abscission of the petals and epinasty of the leaves (data not shown). These effects were completely prevented by pretreatment of the flowers with $500 \text{ nL}\cdot\text{L}^{-1}$ 1-MCP for 6 h (data not shown).

Effect of ethylene inhibitors on fresh weight and vase life. Stocks that had been pretreated with STS or 1-MCP showed greater increase in fresh weight than control flowers (Fig. 2) and significantly ($P < 0.05$) greater longevity, even in the absence of exogenous ethylene. STS-treated flowers remained above their initial fresh weight for 9 d, compared to 6.8 d for 1-MCP and 5.3 d for control flowers. STS was more effective than 1-MCP in maintaining display quality of the flowers (Fig. 3); the difference in display quality was due to earlier inrolling and wilting of florets on the control and 1-MCP-treated stems.

Effect of temperature on respiration. The respiration of the upper 15 cm of stock inflorescences at 20°C was 172.6 ± 7.1 (mean $\pm$ SD)

Table 1. Effects of vase additives [50 ppm NaOCl, 1 mM $\text{Ca}(\text{NO}_3)_2$, commercial preservative] on the percent flower opening (open + dead flowers) on day 10 in vase and vase life of stock inflorescences. Each column shows mean $\pm$ SE of six replicate flowers. Means within column with different letters are significantly different at $P < 0.05$.

Treatments	% Flower opening	Vase life (d)
Control: DI ²	67.6 $\pm$ 4.5 bc	4.6 $\pm$ 0.2 c
50 ppm NaOCl	75.6 $\pm$ 1.5 b	6.2 $\pm$ 0.2 b
1 mM $\text{Ca}(\text{NO}_3)_2$	64.3 $\pm$ 1.1 c	4.6 $\pm$ 0.2 c
$\text{Ca}(\text{NO}_3)_2$ + NaOCl	66.6 $\pm$ 1.6 c	6.2 $\pm$ 0.2 b
Prsv ³	97.0 $\pm$ 1.6 a	10.6 $\pm$ 0.5 a
$\text{Ca}(\text{NO}_3)_2$ + Prsv	91.8 $\pm$ 4.6 a	9.6 $\pm$ 0.2 a

²Deionized water.

³Preservative.

Fig. 1. Effects of vase additives on percent change in fresh weight of stock flowers during vase life. (Δ - Δ) Commercial preservative (prsv); ($\blacktriangle$ - $\blacktriangle$) prsv + $\text{Ca}(\text{NO}_3)_2$; ($\square$ - $\square$) NaOCl; ($\blacksquare$ - $\blacksquare$) NaOCl + $\text{Ca}(\text{NO}_3)_2$; ($\circ$ - $\circ$) DI; ($\bullet$ - $\bullet$) $\text{Ca}(\text{NO}_3)_2$. Vertical bars represent standard errors of six replicate flowers; if no bar is shown, it falls within the dimensions of the plotting symbol.

Fig. 2. Effects of silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) on change in fresh weight of stock flowers held in DI water during vase life.

Fig. 3. Effects of silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) on flower quality of stock flowers after 8 d in the vase.

mL CO₂·(kg·h)⁻¹. Between 0 and 20 °C, respiration increased in an exponential fashion (Fig. 4a). The Q₁₀ for respiration was 6.9 between 0 and 10 °C, 4.4 between 5 and 15 °C, and 3 between 10 and 20 °C.

Effect of storage temperature on vase life. There was a striking reduction in the vase life, at 20 °C, of stock flowers that had been previously stored for 5 d at temperatures from 0 to 15 °C (Fig. 4b).

Relationship between vase life after storage and respiration at different storage temperatures. The vase life at 20 °C of stocks that

had been stored for 5 d at different temperatures was highly linearly correlated with their respiration rates at the respective storage temperatures (Fig. 4c).

Discussion

As shown previously by Nowak and Rudnicki (1976) and Song et al. (1996), a preservative containing a carbohydrate source further prolonged the vase life of stock flowers by improving bud opening and floret longevity (Table 1, Fig. 1).

Contamination of the vase solution is a major postharvest problem for stock flowers, causing early wilting of flowers due to bacterial plugging of the xylem. Previous studies (Nowak and Rudnicki, 1975; Song et al., 1996) showed the beneficial effects of HQS in preventing bacterial development in stocks held in vase solutions containing sucrose. We found similar beneficial effects using NaOCl, which delayed contamination of vase solution, thereby maintaining fresh weight (Fig. 1) and prolonging the vase life of the flowers (Table 1).

In contrast to the results reported by Song et al. (1996), we did not find any effect of calcium in vase solution on the vase life of stock flowers (Table 1, Fig. 1). This difference may be due to different growing conditions, and/or postharvest regimens. We did not test the effect of the Ca(NO₃)₂ on negative gravitropism of the upper part of the spike.

We confirmed previous findings (Serek et al., 1995) indicating the deleterious effects of ethylene on stock flowers and the effectiveness of 1-MCP in preventing those effects. In addition to preventing the deleterious effects of ethylene, these inhibitors markedly extended the display life of flowers held in air (Figs. 2 and 3), suggesting that the natural senescence of stock flowers is coordinated by endogenous ethylene production. The flowers treated with STS lasted longer than those treated with 1-MCP, a phenomenon we have observed in other flowers (Cameron and Reid, 2001) and interpret as an indication of high turnover of ethylene binding sites in the petals. An alternative explanation, that the presence of Ag⁺ might have a beneficial biocidal effect is unlikely due to the very high stability constant (β₂ = 12.63) of the silver thiosulfate anionic

Fig. 4. (a) Respiration rates; (b) vase life in a commercial preservative following storage at various temperatures; and (c) relationship between vase life and respiration of stock flowers at different temperatures. Vertical bars in Fig. 4a and b represent standard errors of three and six replicate flowers, respectively; if no bar is shown, it falls within the dimensions of the plotting symbol. Means with different letters in Fig. 4b are significantly different at $P < 0.05$. The vase life of the nonstored flowers was 13.2 ± 0.8 d (mean $\pm$ sd).

complex (Silln and Martell, 1971).

The experiments reported here clearly demonstrate the importance of proper temperature control in the postharvest handling of stocks. Immediately following removal from storage, the flowers did not show any visible differences, but their vase life at 20 C was strongly affected by storage temperature. As the storage temperature increased, the vase life of flowers after storage was dramatically reduced (Fig. 4b), principally as a result of accelerated petal wilting. The highly significant linear correlation between the respiration and the vase life of stock flowers stored at those temperatures (Fig. 4c) corroborates the importance of respiration during storage on subsequent vase life of cut flowers postulated by Cevallos and Reid (2000).

The Q_{10} for respiration of stock flowers was much higher between 0 and 10 C (6.9) than between 10 and 20 C (3), and similar to that of *Narcissus* (Cevallos and Reid, 2000), one of the highest that we have measured. Q_{10} values for other flowers for this temperature range are typically between 3 and 5 (elikel, Cevallos, and Reid, unpublished). The reason for changes in Q_{10} with temperature, which we have seen in other cut flowers, and is common in other perishable commodities, is not known.

The progressive nature of Q_{10} underscores the importance of even a few degrees difference in temperature close to the freezing point on maintenance of flower quality.

It is interesting to note that the vase life of non-stored stock flowers was exactly the same as that of flowers stored at 0 C, and the vase life/respiration line intersects the ordinate close to the same point. These data indicate that short term storage at the proper temperature yields flowers that are indistinguishable from freshly harvested flowers, and suggest that there is little to be gained in short-term storage of stocks from attempting to further reduce the rate of respiration and aging by the use of techniques such as controlled or modified atmosphere storage.

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