Effects of STS and 1-MCP on Flower Opening and Lifespan of Potted *Kalanchoe blossfeldiana* Exported to Japan

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Abstract. This study was conducted to determine the effects of silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) on flower opening and lifespan of potted *Kalanchoe blossfeldiana* 'Oriba' for exportation. Ethylene inhibitors, STS and 1-MCP were applied to the kalanchoe plants prior to their export to Japan. STS 0.5 mM with 1% Tween 20 surfactant was directly sprayed (20 mL per plant) to leaves, buds, and flowers and 1-MCP 100 $nL \cdot L^{-1}$ was injected into sealed glass chambers containing kalanchoe plants, which were placed on the chambers for 6 hours. After transport to Japan, the plants were immediately transferred to a simulated retail condition room (80 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for 12 hours of photoperiod at 22℃ and 64% RH) at Toyko University. The numbers of buds, open florets, and wilted florets in the middle inflorescence for each plant were counted right after export, 1 week after export, and 6 weeks after export. The percentages of open florets and wilted florets were calculated from the numbers. STS treatment resulted in 35% more open florets than the control and only 11% of wilted florets at 6 weeks after export to Japan which indicate the extension of lifespan of potted kalanchoe plants. Meanwhile, the plants exposed to 1-MCP before export did not show any significant differences in the numbers of buds and open florets and the percentages of open and wilted florets compared to control plants. In conclusion, STS 0.5 mM treatment strikingly induced better opening florets and lifespan of kalanchoe plants from 1 week to 6 weeks after export than control.

***Additional key words*:** open florets, wilted florets

Introduction

The demand for potted plants has risen in Japan, on the other hand, the productivity of floricultural industry in Japan has decreased because of becoming an aging society and increasing labor cost (Korean Rural Economic Institute, 2003). In this aspect, the Korean Rural Economic Institute (2003) reported export of the small-sized potted flower plants with high quality to Japan is a potential strategy to increase rural household incomes.

Kalanchoe blossfeldiana which has various cultivars and flower colors is one of the most popular potted flower plants in the world including Japan (Dole and Wilkins, 2005; Leonard and Nell, 1998). However, kalanchoe plants are so sensitive to ethylene that they hardly open buds and maintain open flowers for a long time (Marousky and Harbaugh, 1979; Serek and Reid, 2000). For example, mechanical stresses such as vibration and shock during shipping for transportation as a common method for export and import induce the accumulation of ethylene and thereby decrease visual appearance and display life of the flowering potted plants, resulting in low quality of potted plants (Bulle et al., 2000; Cushman et al., 1994; Reid and Wu, 1992; Van Doorn and Stead, 1997). Especially, rapid petal inrolling and flower senescence under exogenous ethylene were reported in kalanchoe plants (Dole and Wilkins, 2005; Marousky and Harbaugh, 1979).

Meanwhile, ethylene inhibitors such as silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) are known to extend flower lifespan and reduce bud and flower drop, leaf abscission, and flower senescence by preventing plants against damages from ethylene (Celikel et al., 2002; Jones et al., 2001; Reid et al., 2002; Serek and Reid, 2000; Serek et al., 1994). In many previous studies, STS and 1-MCP showed positive effects in various kalanchoe cultivars (Reid et al., 2002; Serek and Reid, 2000; Serek et al., 1994). Moreover, in our previous study, we determined the effects of STS

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and 1-MCP on flower opening and lifespan of mini-potted kalanchoe plants and their optimum concentrations, 0.5 mM or 1 mM STS and 100 $nL\cdot L^{-1}$ 1-MCP (Park et al., 2009). The study showed potential possibilities for practical usage of the ethylene inhibitors on potted kalanchoe plants for export.

Therefore, the objective of this study was to determine the effects of STS and 1-MCP on flower opening and lifespan of potted *K. blossfeldiana* 'Oriba' under a practical export situation to Japan.

Materials and Methods

Plant Materials

K. blossfeldiana 'Oriba' was grown in a commercial farm, Gyeonggi-do, South Korea. Each plant was cultivated in a 10-cm pot. Fifty kalanchoe plants at bud stage were purchased for this experiment.

Ethylene Inhibitors

Purchased plants were kept for 5 days in a growth chamber equipped with fluorescence lamps and metal halide lamps (Duri Science, DF-95G-1485, Bucheon, Korea) (200 $\mu mol\cdot m^{-2}\cdot s^{-1}$ for 12 hours of photoperiod at 20℃ and 50% RH) at Konkuk University, Seoul, South Korea before export to Japan. After 5 days, the plants were treated with STS and 1-MCP prior to export. STS 0.5 mM with 1% Tween 20 surfactant was directly sprayed (20 mL per plant) to the leaves, buds, and flowers of kalanchoe plants (Auer and McConnell, 1984). Gaseous 1-MCP 100$nL\cdot L^{-1}$ was injected into the sealed glass chambers containing kalanchoe plants and the plants were placed on the chambers for 6 hours (Serek and Reid, 2000). Air in the chambers was circulated by a fan at 22℃.

Export Conditions and Process

All the plants were sleeved with vinyl bags and randomly put into cardboard boxes (65 × 45 × 25 cm) to export after the STS or 1-MCP treatment. To monitor the temperature and relative humidity inside and outside the boxes during transportation, sensors (LTH-8K, KIWI Instruments, USA) were attached to three different places of a box such as outside of the box, middle part of the inner box which was near the florets, and bottom of the inner box. Export process was the same as the practical methods used by representative Korean company (Gyeonggi Floricultural Cooperative Alliance Fleur) for export of small-sized potted plants to Japan. The specific export process was indicated in Fig. 1. The kalanchoe plants in 6 boxes (9 plants/box) were transported to a floricultural market in Yangjae-Dong, Seoul, South Korea by truck from Konkuk University, Seoul, South Korea. The plants were then loaded in a container (12℃ and dark condition) for export to Japan. The container was transported to Busan in South Korea by truck to take a ferry for shipping to Hukuoka in Japan. After passing quarantine at Hukuoka in Japan, the plants were collected in a place for load collection at Keiyo in Japan and then transported to a laboratory at Toyko University in Japan. The plants were immediately transferred to a simulated retail condition room equipped with fluorescence lamps (80 $\mu mol\cdot m^{-2}\cdot s^{-1}$ for 12 hours of photoperiod at 22℃ and 64% RH) and watered once a week. It took 5 days to transport the plants from South Korea to Japan by truck and ship.

Measurement Parameters

The numbers of buds, open florets, and wilted florets in the middle inflorescence in each plant were counted (Serek and Reid, 2000) right after export, 1 week after export, and 6 weeks after export. Nine plants per treatment were used. Based on the numbers of buds, open florets, and wilted florets, the percentages of open and wilted florets were calculated as followed:

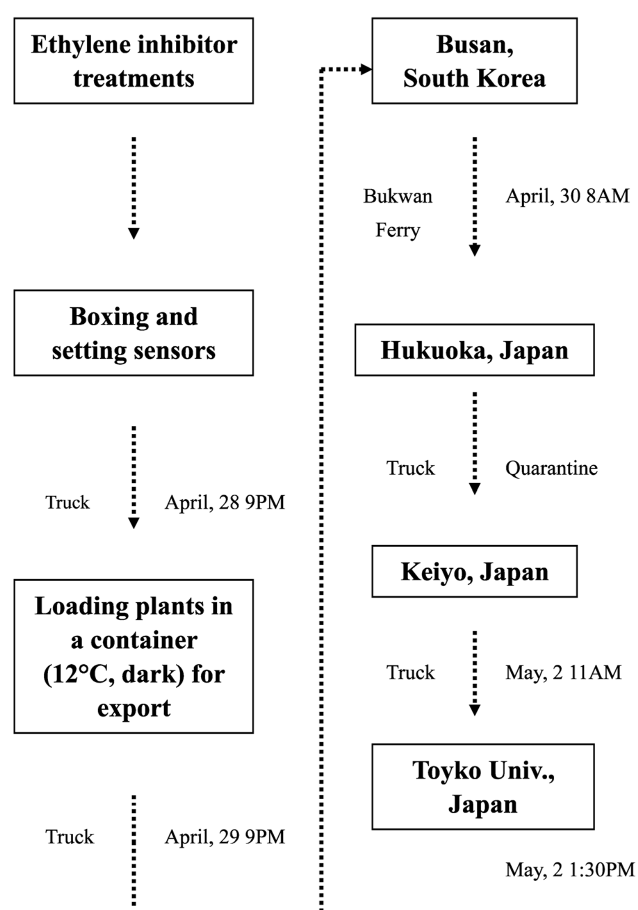

Fig. 1. Time schedule for the export of potted kalanchoe from South Korea to Japan in this study.

$$\% \text{ of open florets} = \frac{\text{The number of open florets}}{\text{Sum of the numbers of buds, open florets, and wilted florets}} \times 100$$

$$\% \text{ of wilted florets} = \frac{\text{The number of wilted florets}}{\text{Sum of the numbers of buds, open florets, and wilted florets}} \times 100$$

Data Analysis

A completely randomized experimental design was used. Analysis of variance (ANOVA) was performed by the Statistical Analysis System (SAS version 9 for Windows, SAS Institute Inc, Cary, NC). Duncan's multiple range tests was used to compare the means.

Results and Discussion

Ethylene Iinhibitors Efficacy on Flower Opening and Lifespan of Potted *K. blossfeldiana* 'Oriba' Right after Export

There was no significant difference in the number of inflorescence and buds and the percentages of open florets and dead florets right after export (0 week) (Figs. 2, 3, 4, and 5). This means that kalanchoe plants we used had similar quality in terms of flower and it was too early to see any effects of ethylene inhibitors on the bud and florets at the time.

Ethylene Inhibitors Efficacy on Flower Opening and Lifespan of Potted *K. blossfeldiana* 'Oriba' at 1 Week after Export

The effect of the STS was first exhibited at the 1^{st} week after the export to Japan. Kalanchoe plants treated with STS had significantly greater numbers of buds and open florets than the control and 1-MCP-treated plants (Figs. 2 and 3). STS induced more open florets from buds than the other treatments so that it allowed a fuller floral display, resulted in increased consumer preference at the 1^{st} week after export when it is a sales period. Consisted with this result, STS treatments made buds of kalanchoe plants open effectively and prevented premature wilting caused by ethylene in our previous study (Park et al., 2009). In addition, bud opening was inhibited under external ethylene in carnations (Reid and Wu, 1992) and STS promoted bud opening of sweet pea (Mor et al., 1984; Sexton et al., 1995). However, no

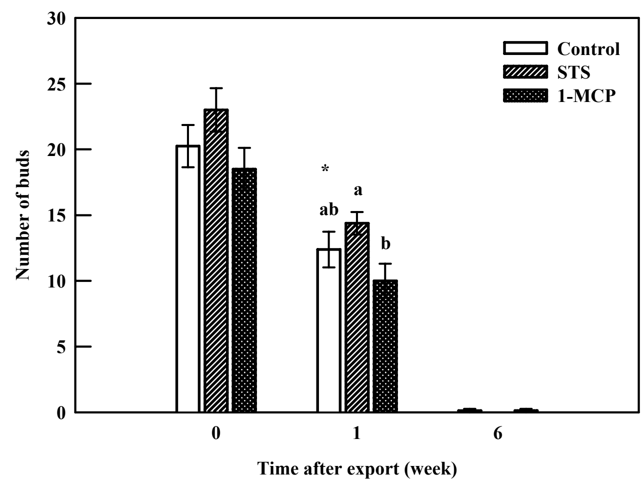

Fig. 3. The number of buds of potted *Kalanchoe blossfeldiana* 'Oriba' after export to Japan. STS 0.5 mM or 1-MCP 100 $nL \cdot L^{-1}$ were treated with the kalanchoe plants right before export. Vertical bars indicate the standard errors (n = 9). Significant differences at *P* = 0.05(*) within the time after export are indicated by letters.

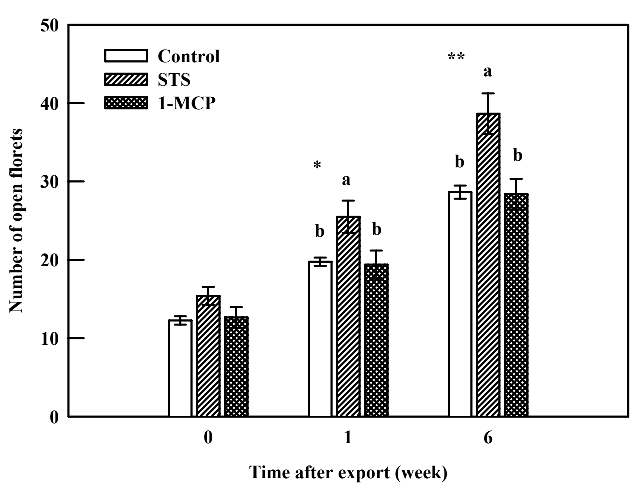

Fig. 2. The number of open florets of potted *Kalanchoe blossfeldiana* 'Oriba' after export to Japan. STS 0.5 mM or 1-MCP 100 $nL \cdot L^{-1}$ were treated with the kalanchoe plants right before export. Vertical bars indicate the standard errors (n = 9). Significant differences at *P* = 0.05(*) or 0.01(**) within the time after export are indicated by letters.

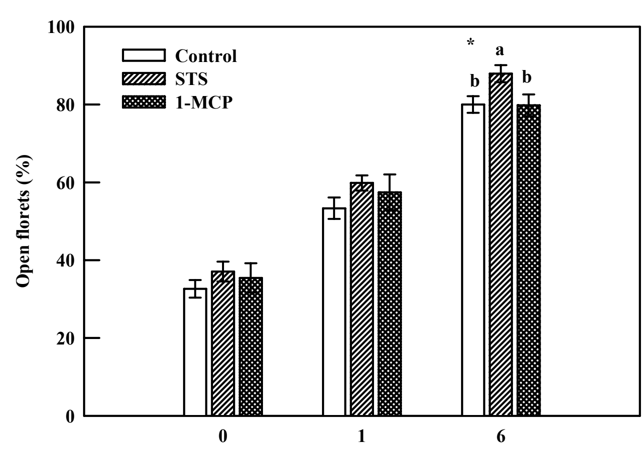

Fig. 4. The percentage of open florets of potted *Kalanchoe blossfeldiana* 'Oriba' after export to Japan. STS 0.5 mM or 1-MCP 100 $nL \cdot L^{-1}$ were treated with the kalanchoe plants right before export. Vertical bars indicate the standard errors (n = 9). Significant differences at *P* = 0.05(*) within the time after export are indicated by letters.

significant effect of 1-MCP on flower opening and lifespan was detected at this time. Thus, this result suggested that STS started to effectively control endogenous or exogenous ethylene for opening buds at 1 week after export.

Ethylene Inhibitors Efficacy on Flower Opening and Lifespan of Potted *K. blossfeldiana* 'Oriba' at 6 Week after Export

Kalanchoe plants treated with STS continuously had a significant raise in the number of open florets and opening florets rate than the control and 1-MCP-treated plants (Figs. 2 and 4). STS treatment resulted in a 35% increase in the open florets than the control and 1-MCP-treated plants, making a fuller floral display at 6 weeks after export. This result is very noticeable where this time is a display period for consumer. Moreover, there was significant difference in wilted florets treated with STS at 6 weeks after the export (Fig. 5). STS-treated plants had only 11% of wilted florets at this time suggesting pretty low number of wilting florets. Finally, the low numbers of wilted florets could extend the lifespan of kalanchoe flowers exposed to STS before export. In our previous study, 0.5 mM and 1 mM STS treatments completely protected kalanchoe plants from the wilting of the open florets until 5 weeks after simulated export and leaded to low wilting rate of the open florets even after 7 weeks of simulated export (Park et al., 2009). Furthermore, the effect of STS on low wilting rate was reported in other flower species such as begonia, schefflera, rose, and sweet pea (Auer and McConnell, 1984; Bulle et al., 2000; Cushman et al., 1994; Mor et al., 1984).

Compared to STS, 1-MCP did not work in inducing and maintaining open florets both after and 6 weeks after export

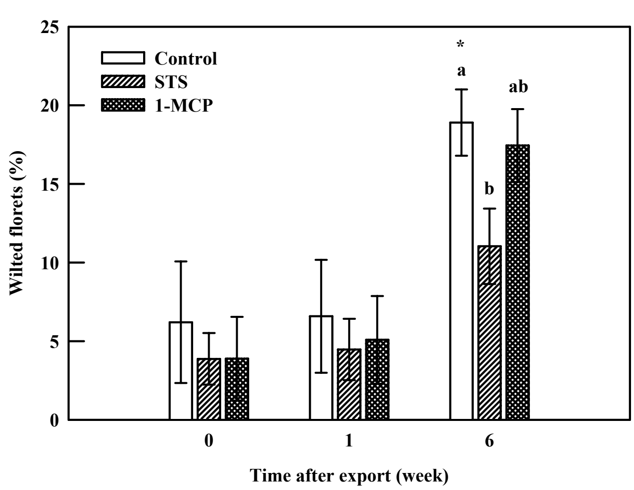

Fig. 5. The percentage of wilted florets of potted *Kalanchoe blossfeldiana* 'Oriba' after export to Japan. STS 0.5 mM or 1-MCP 100 nL·L^{-1} were treated with the kalanchoe plants right before export. Vertical bars indicate the standard errors (n = 9). Significant differences at P = 0.05(*) within the time after export are indicated by letters.

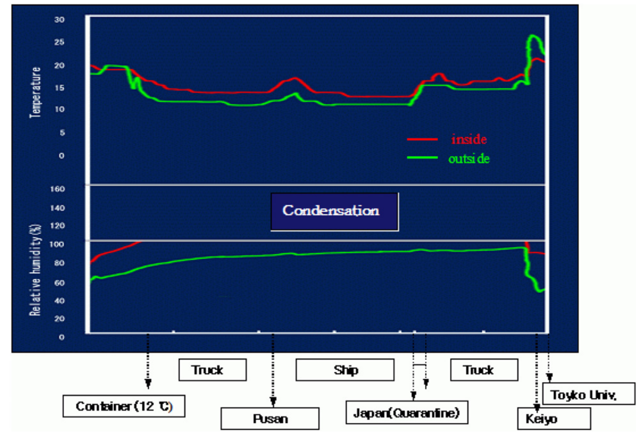

Fig. 6. Temperature and relative humidity during transport from South Korea to Japan measured by a sensor (LTH-8K, KIWI Instruments, USA).

in this study (Figs. 2, 4, and 5). Although the efficacy of 1-MCP as an ethylene inhibitor had been already evaluated in several flower plants including kalanchoe (Reid and Wu, 1992; Serek and Reid, 2000; Serek et al., 1994; Park et al., 2009), 1-MCP treatment did not affect the longevity of individual floret of kalanchoe plants because gaseous 1-MCP binds ethylene in plants blocking the negative effects of ethylene but newly-produced ethylene receptors combine with endogenous ethylene again resulting in flower senescence along with the time (Serek and Reid, 2000; Serek et al., 2006). In other words, 1-MCP acts for a limited time as an ethylene inhibitor so that the effect on flower lifespan for a longer period was minimal compared to STS sprayed and absorbed into plants.

Temperature and relative humidity of inside and outside boxes were measured by sensors during the transport from South Korea to Japan. The temperature was maintained at 12℃ during the whole transportation process, but the condensation inside of the boxes resulted from high relative humidity until arriving at Keiyo in Japan (Fig. 6). Although inside condition of the boxes was unfavorable for the kalanchoe plants, no visual damages on flowers or leaves by condensation were observed.

In summary, 0.5 mM STS treatment showed significantly higher floret opening rate and longer lifespan of *K. blossfeldiana* 'Oriba' after export to Japan than control. Although 1-MCP is known to be effective as much as STS for the lifespan of kalanchoe florets in other studies, the effect of 1-MCP was not detected after the export in this study.

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