Ethylene Production and Vase Life of Cut Carnation Flowers under High Temperature Conditions

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Summary

Cut flowers of carnation 'Excerea', treated with or without silver thiosulfate (STS) showed the same vase life as when kept in Misaki, a commercial preservative, or 1 to 2% fructose with germicide at 32°C. In-rolling of petals did not occur at 32°C until day 14, even though flowers were not treated with STS. However, flowers without STS treatment showed in-rolling on day 9 at 24°C. Flowers without STS treatment, reached a climacteric peak of ethylene during day 8 to 10 at 24°C, whereas flowers at 32°C produced very little ethylene. Flowers, kept at 32°C and then transferred to 24°C, showed a climacteric peak of ethylene, but the peak was lower than that at continuous 24°C. Flowers, kept at 24°C for 1–5 days and then transferred to 32°C, produced very little ethylene. These results suggest that high-temperature keeping conditions inhibit ethylene production in cut carnation flowers.

Key Words: carnation, ethylene, high temperature.

Introduction

Carnation is a typical, ethylene sensitive flower. It has been well-documented that carnation flowers produce ethylene through an autocatalytic reaction to engender rapid flower senescence (Borochoy and Woodson, 1989; Van Altvorst and Bovy, 1995). The application of ethylene-blocking agents has been used to extend the vase life of carnations (Brandt and Woodson, 1992; Sisler and Serek, 2001; Veen, 1979; Wawrzynczak and Goszczynska, 2003). Most studies on flower longevity have been carried out under moderate temperatures. Senescence of cut carnation flowers under high temperature conditions remains unclear. Only short-term exposure to high temperatures has been studied from the viewpoint of pest control and temperature fluctuation during transportation (Maxie et al., 1973; Verliden and Woodson, 1998). It is known that ethylene production of some fruits is inhibited under high temperatures (Eaks, 1978; Maxie et al., 1974). We compared the vase life and ethylene production of cut carnation flowers at 24°C and 32°C. Results of this study show that high temperatures depress ethylene production in cut carnation flowers.

Materials and Methods

Plant Materials

Cut flowers of carnation (*Dianthus caryophyllus* L.

'Excerea') that had been harvested in the morning by a grower (Shionoe, Kagawa) were transported to our laboratory in the afternoon. The flowering stage of the carnation was stage VI, a few days before anthesis, according to Cywinska-Smoter et al. (1978) and Koyama and Uda (1994). The high quality cut flowers were 60–70 cm long and ca. 30 g. Stems were cut to 45 cm, then kept in 0.2 mM silver thiosulfate (STS) (KC-20; Pokon Chrysal Japan, Osaka) or de-ionized water (water) overnight at 4°C. The following morning, all flowers were packed with dry newspapers in a box and stored at 25°C for one day. Then all flowers were re-cut to 40 cm, which eliminated some basal leaves. The flowers were kept in 500 mL water or vase solution. Each treatment had three replications that consisted of three flowers per flask. The flowers were kept at 24°C or 32°C under a light intensity of 20 $\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$, provided by fluorescent lamps with a 16-h photoperiod. The fresh weight of cut flowers, water consumption, and symptoms of senescence of the flowers were recorded every morning. The vase life of flowers was terminated when petal in-rolling occurred or petal color faded.

Experimental design

In the first experiment, the vase life of cut carnation flowers harvested on October 15, 2003, and treated with or without STS were compared at 24 or 32°C. In addition, cut flowers in each temperature treatment were kept in Misaki, a commercial preservative (Otsuka Chemical Co., Ltd. Osaka) to test its effect on vase life.

In the second experiment, flowers harvested on December 10, 2003 were treated with or without STS.

Received; September 24, 2004. Accepted; February 4, 2005.

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Then they were kept in vase solution which contained 0, 1, 2 or 3% fructose and $0.5 \text{ mL} \cdot \text{L}^{-1}$ Legend MK (anti-microbial compound; Rohm and Haas Co., USA) at 32°C . Vase life data were analyzed by using analysis of variance and Tukey's multiple range test.

Ethylene production of flowers at 24°C or 32°C was measured in the third and fourth experiments. In the third experiment, flowers were harvested on April 4, 2004 and kept in 1% fructose and $0.5 \text{ mL} \cdot \text{L}^{-1}$ Legend MK without STS treatment. The flowers were placed at 24°C or 32°C continuously, or 32°C for one day and then transferred to 24°C . In the fourth experiment, flowers, harvested on May 12, 2004, were immersed in solutions comparable to experiment three and kept at 24°C or 32°C continuously, or 24°C for 1, 3, or 5 days and transferred to a 32°C environment.

Ethylene measurement

A flower for ethylene measurement was enclosed in a jar (144 mL) and incubated at 24°C or 32°C for 1 h. One-mL of headspace gas was extracted and injected into a gas chromatograph (Porapak Q, GC-14B; Shimadzu Corp. Kyoto). Ethylene production of flowers was measured every morning for 2 weeks. Four flowers were used in each measurement.

Results and Discussion

Vase life of cut carnation flowers under high temperature conditions

The vase life of cut carnation flowers with or without STS treatment did not differ ca. 13 days when they were kept in Misaki at 32°C (Fig. 1) and in-rolling did not occur, even in flowers without STS treatment. However, vase life of control flowers kept in water at 32°C was significantly ($P < 0.05$) shortened compared to that of flowers kept in Misaki. The fresh weight of flowers with or without STS treatment kept in Misaki at 32°C increased in the first week, then decreased slightly, but less so in STS treated flowers (Fig. 2B), whereas flowers kept in water quickly lost weight after 3 days. Not only was vase life shortened, but cut ends of flower stems kept in water became pale brown, which indicated bacterial proliferation.

Petals of flowers without STS treatment and kept in Misaki at 24°C showed in-rolling on day 9, associated with their decrease in fresh weight on day 8 (Fig. 2A). In contrast, the fresh weight of flowers treated with STS and kept in Misaki increased during the first 6 days, then decreased slightly until day 20. These flowers had the longest vase life (Fig. 1). The vase life of flowers kept in water at 24°C was as short as that of flowers kept at 32°C . The difference in the vase life between Misaki and water may be attributed to the flowering stage of cut carnation. The flowers were in stage VI, a few days before full opening. Opening of cut carnation flowers requires energy and water uptake. We infer that the flowers, kept

in water, did not get a sufficient energy supply which resulted in a shorter vase life.

Flowers, without STS treatment and kept in Misaki at 32°C , showed no typical ethylene-induced symptoms, whereas comparable flowers at 24°C showed in-rolling and wilted completely within 2 weeks (Fig. 3), suggesting that the flowers did not produce ethylene at 32°C . It was unclear whether this unusual result was attributed to the effect of Misaki, which contains about 1% fruc-

Fig. 1. Vase life of cut flowers of 'Excerea' carnation treated with and without STS and kept in Misaki (commercial preservative) or water at 24°C or 32°C . Values with different letters are significantly different ($P < 0.05$) by Tukey's multiple range test ($n=9$).

Fig. 2. Fresh weight of cut flowers of 'Excerea' carnation treated with or without STS and kept in Misaki (commercial preservative) (M) or water (W) at 24°C (A) or 32°C (B). Vertical bars indicate SE ($n=3$).

Fig. 3. Cut flowers of 'Excerea' carnation without STS treatment kept in Misaki (commercial preservative) for 13 days at 24°C (A) or 32°C (B).

Fig. 5. Ethylene production during the vase life of cut flowers of 'Excerea' carnation kept at 24 or 32°C continuously, or 32°C for 1 day then transferred to 24°C. Vertical bars indicate SE (n=4).

tose, based on HPLC analysis (data not shown) and other unknown elements. To clarify this point, flowers with and without STS treatment were kept in a simple solution containing fructose and germicide at 32°C. Flowers without STS kept in 1 and 2% fructose had a vase life equivalent to STS-treated flowers (Fig. 4). Most flowers without STS showed no in-rolling regardless of vase solution: a few exceptional flowers had a few petals inside the flower that showed in-rolling at 32°C, confirming that flowers produced little or no ethylene.

Petals gradually turned pale and became dry at 32°C, but in-rolling did not occur. Flowers, kept in 1% fructose, kept their vivid petal color longer than flowers kept in water. High fructose concentrations (2 and 3%, especially 3%) caused yellowing of the calyx and

Fig. 4. Vase life of cut flowers of 'Excerea' carnation treated with or without STS and kept at 32°C in 0, 1, 2, or 3% fructose. Values with different letters are significantly different ($P<0.05$) by Tukey's multiple range test (n=9).

Fig. 6. Ethylene production during the vase life of cut flowers of 'Excerea' carnation kept at 24 or 32°C continuously, or 24°C for 1, 3, or 5 days then transferred to 32°C. Vertical bars indicate SE (n=4).

engendered a shorter vase life. Koyama and Uda (1994) reported pale petal color in cut carnation flowers that opened at 30°C. Even though in-rolling did not occur, earlier senescence of flowers – fading petal color and morphology changes – was unavoidable under high temperature conditions.

Ethylene production under high temperature conditions

Flowers kept at 24°C attained a climacteric peak of ethylene production between days 8–10, whereas flowers at 32°C produced only a very small amount of ethylene (Fig. 5). Flowers kept under alternating 32°C and 24°C also produced ethylene, but the peak of ethylene production was lower than that of flowers kept continuously at 24°C. In the second ethylene measurement, flowers kept at 32°C again produced very little ethylene, whereas flowers reached a climacteric peak of

ethylene production on day 9 at 24°C (Fig. 6). Flowers kept at 24°C for 1, 3 or 5 days and transferred to 32°C also evolved a low level of ethylene. Verlinden and Woodson (1998) reported delayed production of ethylene and related enzymes in cut carnation flowers that were exposed to 44°C for 24 h, suggesting that high temperature blocks ethylene biosynthesis in cut carnation flowers.

At temperatures at or over 30°C, avocado and pear do not ripen normally because they are unable to produce ethylene (Eaks, 1978; Maxie et al., 1974). Yu et al. (1980) reported that 1-aminocyclopropane-1-carboxylate (ACC) accumulation occurred in apple and mung bean tissues, but the failure to produce ethylene under high temperature, suggests an inhibition of ACC conversion to ethylene. In tomato fruits transferred from 25°C to 35 or 45°C, ACC synthase activity declined rapidly (Biggs et al., 1988); Atta-Aly (1992), likewise, reported that, at 35°C, both ACC synthesis and its conversion to ethylene were inhibited in tomato. It remains unclear whether related enzymes' activity or gene expression is suppressed in this inhibition of ethylene production in cut carnation flowers. Further studies are in progress to address specifically their enzyme-related activity and gene expression in cut carnation flowers under high temperature conditions.

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高温条件下でのカーネーション切り花の品質保持とエチレン生成

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摘 要

STS 無処理または処理のカーネーション (品種エクセリア) の切り花を用い, 24℃または 32℃で品質保持とエチレン生成を比較した. 24℃では, STS 処理によりカーネーションの品質保持期間は延長され, STS 無処理のカーネーションでは, 処理 9 日後から花卉の in-rolling が観察された. 32℃では STS 無処理のカーネーションにおいても, 処理 14 日後でもなお花卉の in-rolling が認められず, STS 処理した区と同等の品質保持期間を示した. STS 無処理のカー

ネーションでは, 24℃では処理 8-9 日後にエチレン生成のピークが認められたが, 32℃ではごく微量のエチレン生成にとどまった. 32℃に 1 日置きその後 24℃に移した区では, 24℃一定の区と同様のエチレン生成のピークが認められた. 一方, 24℃に 1-5 日置き, その後 32℃に移した区ではエチレン生成はごく微量であった. 以上の結果より, カーネーションの切り花は, 32℃におかれた場合, エチレン生成が抑えられることが明らかとなった.