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Improvement of Postharvest Life in Several Cut Flowers by the Addition of Sucrose

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Abstract

Sugars play important roles in keeping the quality of cut flowers because the amount of sugar contained in cut flowers is limited. Effects of sucrose treatment on the vase life of several cut flowers were investigated. Continuous treatment with sucrose markedly promoted floret opening and extended the vase life of cut sweet pea flowers. Pulse treatment with sucrose was also fairly effective in improving the vase life of these flowers. Continuous treatment with sucrose increased anthocyanin concentrations in petals as well as extended the vase life of several cultivars of cut *Eustoma* flowers. This treatment was also effective in improving the vase life of cut snapdragon flowers. Although pulse treatment with sucrose was fairly effective in improving the vase life of cut hybrid *Limonium*, pulse treatment with sucrose in combination with α-aminoisobutyric acid (AIB), an ethylene biosynthesis inhibitor, was markedly effective in improving the vase life. Role of the application of sucrose to cut flowers was reviewed and discussed.

Discipline: Horticulture
Additional key words: *Eustoma grandiflorum*, hybrid Limonium, snapdragon, sugar, sweet pea

Introduction

In Japan, cut flowers have been increasingly distributed in markets along with the increase of flower production in recent years. Furthermore, transportation of cut flowers over long distances has increased. These conditions are unsuitable for keeping the quality of cut flowers. Development of postharvest technology in cut flowers is, thus, being promoted.

Sugars play important roles in plants as substrates for respiration and cell walls as well as osmolytes. Since the amount of sugar contained in cut flowers is limited, the addition of sugars such as sucrose to vase water is effective in improving the vase life of some cut flowers[8].

In this report, I described the role of sugars in improving the vase life of cut flowers. Furthermore, here I reported the improvement of the vase life of cut sweet pea, hybrid *Limonium*, *Eustoma* and snapdragon flowers by treatment with sucrose.

Role of sugars in cut flowers

Addition of sugars to vase water not only extends the vase life of cut flowers but also promotes flower opening. Furthermore, the expression of the flower color is improved by treatment with sugars in some cut flowers such as carnation[14]and rose[7,27]. Effects of sugars on the extension of the vase life of cut flowers are considered to be associated with the improvement of the water balance. However, since inorganic ions did not extend the vase life more than sugar[19], it is suggested that the effect of sugars on the improvement of the vase life is due not only to the effect of osmolytes but also to that of substrates of respiration and synthetic materials.

1) *Promotion of flower opening by sugars*

A large amount of soluble carbohydrates is required for flower bud opening as substrates for cell walls and respiration as well as for their osmotic properties. Since the carbon source of cut flowers is limited, addition of sugars such as sucrose and glucose to vase water is highly effective in promoting flower opening[5,6,18,28].

Petal growth associated with flower opening results from cell expansion[14], which is required for the influx of water and osmolytes such as sugars into cells. In hybrid *Limonium* and carnation, the concentration of sucrose in petals decreased, and that of glucose and fructose increased[23,31,36]. In *Hemerocallis*, fructans are degraded to monosaccharides during flower opening[2]. Monosaccharides derived from sucrose or fructans increase the osmotic pressure, which contributes to flower opening. Woodson and Wang (1987)[36] showed with carnation that these changes in the sugar composition are accompanied with the increase in invertase activity.

2) Extension of longevity of cut flowers

In many cut flowers, sugars such as sucrose extend the vase life. We observed that sucrose extends the vase life of cut sweet pea flowers.

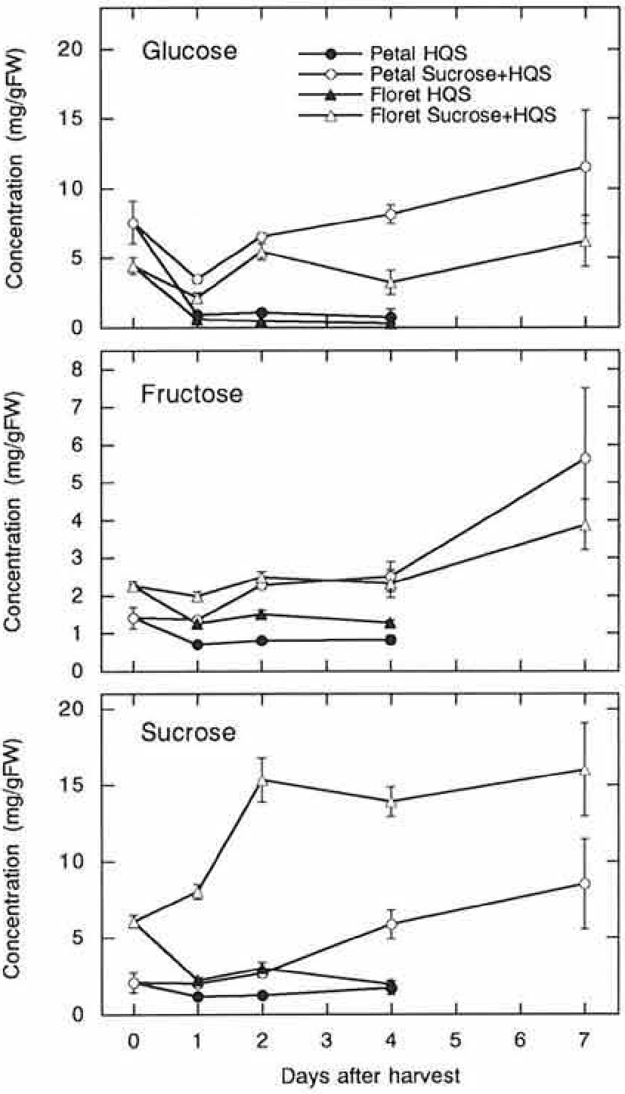

Fig. 1. Changes in sugar concentrations of petal and the other parts of sweet pea floret with time
Values are means of 3 replications ± standard errors. Cut sweet pea flowers were kept at 23°C. HQS solution was used as control.

Flowers of sweet pea are highly sensitive to ethylene[22,25,35], and the vase life is very short. When cut spikes of sweet peas were treated with 40 g L^{-1} sucrose, the vase life became twice as long[12]. This treatment increased the glucose, fructose and sucrose concentrations (Fig. 1) and inhibited ethylene production of florets (Fig. 2). These findings suggest that the sugar concentration increased by the sucrose treatment may lead to the inhibition of ethylene production.

To further clarify the relationships between ethylene production and the sugar concentration of flowers, cut spikes were treated with sucrose continuously (continuous treatment) or only for 24 h (pulse treatment) after harvest. Vase life of control spikes was about 3 days. The continuous and pulse treatments with sucrose extended the vase life of spikes by 8 and 6 days, respectively. Climacteric ethylene production was advanced by the pulse treatment compared to continuous treatment. Furthermore, the sugar concentration decreased with the time after pulse treatment whereas it remained at a high level by continuous treatment. Therefore, ethylene production was largely affected by the sugar concentration in floret.

To determine whether sucrose inhibits the ethylene action, the effect of sucrose on ethylene production of floret was compared to that of silver thiosulfate complex (STS), an ethylene action inhibitor[9]. Although sucrose inhibited ethylene production more than STS (Fig. 3), STS extended the vase life more than sucrose. STS is known to suppress autocatalytic ethylene production by in-

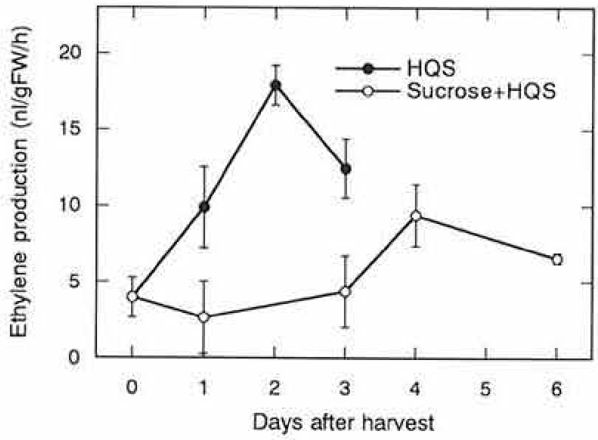

Fig. 2. Changes in ethylene production of sweet pea floret with time
Values are means of 3 replications ± standard errors. Cut sweet pea flowers were kept at 23°C. HQS solution was used as control.

hibiting ethylene action. These findings suggest that sucrose may not inhibit the ethylene action although it remains to be determined whether sucrose directly inhibits ethylene production.

3) *Improvement of flower color expression by sucrose*

Treatment with sugars such as sucrose improved the expression of petal colors in some cut flowers such as rose[7,27], sweet pea[9] and *Eustoma*[11]. Pigments of these flowers are mainly anthocyanins.

Anthocyanins are synthesized via several enzymatic steps such as chalcone synthase and chalcone flavanone isomerase[4]. Tsukaya et al. (1991)[32] and Moalem-Beno et al. (1997)[21] reported that in petunia the gene expression of chalcone synthase, a key enzyme of anthocyanin biosynthesis was induced by sucrose. Similarly, Kusuhara et al. (1996)[16] reported that in *Eustoma* sucrose increased the expression of genes involved in anthocyanin biosynthesis such as chalcone isomerase, dihydroflavanone reductase and chalcone synthase. Thus, the stimulation of anthocyanin expression of cut flowers by sucrose may be involved in the promotion of anthocyanin biosynthesis gene expression. Furthermore, this promotive effect is possibly due to the supply of sugars as glycoside residues of anthocyanin because anthocyanins are usually present as glycosides.

To determine whether the amount of other flower pigments such as carotenoid and betacyanins increased by sugar treatment, further studies will be required.

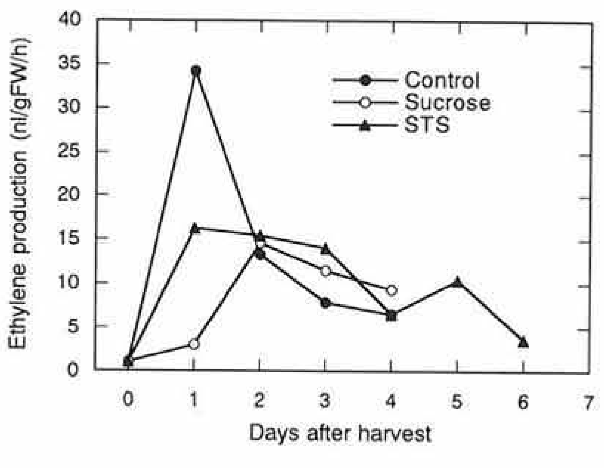

Fig. 3. Changes in ethylene production of sweet pea floret with time
Cut sweet pea flowers were kept at 23°C. Flower spikes were treated with water (control), 0.2 mM STS, and 100 g L^{-1} sucrose.

Effects of sucrose treatment on the vase life of various cut flowers

Since sugars such as sucrose are effective in improving the vase life of cut flowers, they are included in preservatives. I describe here that sucrose improves the vase life of several important cut flowers.

1) *Sweet pea*

Sweet pea (*Lathyrus odoratus* L.) is a very suitable cut flower because of its wide range of colors and exceptional fragrance. The vase life of the cut flowers is very short[22,25,35]. Since the flower of sweet pea is sensitive to ethylene, STS has been shown to be very effective in prolonging the vase life of sweet pea[13,22,30]. STS, however, contains silver, a heavy metal, which is a potent environmental pollutant. Therefore, other chemicals will be required. Aminooxyacetic acid[3], α-aminoisobutyric acid[26,29], aminoethoxyvinyl glycine[1] and 1,1-dimethyl-4-phenylsulfonylsemicarbazide[20], inhibitors of ethylene biosynthesis, have been found to be effective in prolonging the longevity of cut carnation flowers. These compounds, however, are only slightly effective in extending the vase life of cut sweet pea flowers[33]. On the contrary, diazocyclopentadiene, an ethylene action inhibitor, is fairly effective in extending the longevity of cut sweet peas[30].

We therefore investigated the effect of sucrose on the vase life of bud-cut sweet peas. Continuous treatment with sucrose markedly promoted floret opening and extended the floret longevity in cut sweet peas[12]. The vase life of florets treated with 100 g L^{-1} sucrose was 3 times longer than that of control florets.

Although STS is a potent environmental pollutant, the use of this compound is not prohibited as preservative. We thus examined the effects of pulse treatment with sucrose and STS on the vase life of sweet pea flowers harvested at conventional times for farmers[9]. The cut spikes were treated with 100 g L^{-1} sucrose for 16 h, 0.2 mM silver thiosulfate complex (STS) for 2 h and 0.2 mM STS for 2 h followed by 100 g L^{-1} sucrose for 16 h. Treatment with STS followed by sucrose was the most effective in promoting floret opening (Fig. 4) as well as extending the vase life (Table 1). Anthocyanin concentrations increased by treatments with sucrose alone or STS followed by sucrose (Table 2). These results show that the addition of STS followed by sucrose

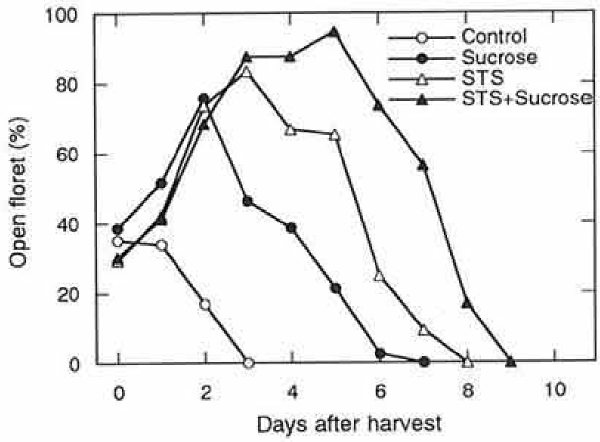

Fig. 4. Effect of combined treatment with STS and sucrose on floret bud opening
Cut sweet pea flowers were kept at 23°C. Flower spikes were treated with water (control), 0.2 mM STS, 100 g L^{-1} sucrose and 0.2 mM STS followed by 100 g L^{-1} sucrose. Data were taken from only the bud with maximum growth of each flowering stem.

Table 1. Effects of combined treatment with sucrose and STS on the vase life of cut sweet pea flowers

Treatment	Vase life (days)	
	Floret	Spike[a)]
Control (water)	1.7	2.5
Sucrose (100 g L^{-1})	3.0	5.9
STS (0.2 mM)	4.4	7.2
STS (0.2 mM) + Sucrose (100 g L^{-1})	6.0	8.7

a): Vase life of spikes was determined as the time from harvest to the time when all the florets wilted.
Cut flowers were kept at 23°C.

Table 2. Effects of combined treatment with sucrose and STS on anthocyanin concentrations of petals in cut sweet pea flowers

Treatment	Anthocyanin (OD530 nm gFW^{-1})
Control (water)	0.84
Sucrose (100 g L^{-1})	2.62
STS (0.2 mM)	1.11
STS (0.2 mM) + Sucrose (100 g L^{-1})	1.76

Cut flowers were kept at 23°C.

is more effective than that of STS alone in improving the vase life of cut sweet pea flowers.

As mentioned above, the use of STS is not recommended. Since the treatment with sucrose alone was also considerably effective in improving the vase life of cut sweet pea, it is assumed that the use of sucrose in combination with ethylene inhibitors, other than STS, may improve the vase life of sweet pea in the same way as STS.

2) *Hybrid* Limonium

Hybrid *Limonium*, cultivar 'Blue fantasia 100', is an interspecific hybrid between *L. bellidifolia* Gouan and *L. latifolium* Kuntzn. The inflorescence has many small florets, which are at various developmental stages between bud and opened floret. In the cut inflorescence, buds seldom open and the floret longevity is short. Thus, the effects of sucrose on the vase life of hybrid *Limonium* were investigated[31].

The cut flowers were treated with sucrose for 24 h, and thereafter placed in water. Sucrose at 10 and 20 g L^{-1} significantly increased the percentage of open florets, but did not affect appreciably the floret senescence. Since sucrose alone did not improve the vase life sufficiently, we further examined the effect of combined treatment with 20 g L^{-1} sucrose and 10 mM α-aminoisobutyric acid (AIB), an inhibitor of 1-aminocyclopropane-1-carboxylic acid (ACC) oxidase on the vase life. The combined treatment with sucrose and AIB promoted floret opening and inhibited floret senescence. This effect is probably due to the promotion of floret opening by sucrose and extension of longevity by AIB. Petal color was expressed well and florets fully opened after the treatment. Therefore, this treatment can be practically used as preservative for farmers.

3) Eustoma

Eustoma grandiflorum (Raf.) Shinn., which is native to the southern United States, was introduced into Japan more than 60 years ago. *Eustoma* is widely produced in the world, particularly in Japan. Although the vase life of cut *Eustoma* flowers is relatively long, small buds do not open fully and the color of petals is slightly expressed. We therefore investigated the effect of sucrose with 8-hydroxyquinoline sulfate (HQS) on the vase life in 6 cultivars of *Eustoma* flowers[11].

Continuous treatment with 20 g L^{-1} sucrose combined with 200 mg L^{-1} HQS significantly promoted flower opening and extended the vase life of all the cultivars tested (Table 3). This treatment also increased anthocyanin concentrations of petals, particularly in 'Azuma-no-ginga' and 'Azuma-no-kasumi', both of which show a light color (Table 4).

Cut *Eustoma* flowers used in this study were

Table 3. Effect of sucrose with HQS on vase life in various cultivars of cut *Eustoma grandiflorum*

Cultivar	Vase life[a] (days)	
	Control (water)	Sucrose + HQS
Azuma-no-ginga	9.8	14.4
Azuma-no-kasumi	11.1	16.0
Azuma-no-shirabe	14.4	20.1
Piccolo blue	10.7	19.0
Piccolo blue picoty	11.9	24.0
Piccolo rose	12.4	19.4

a): Vase life was determined as the time from harvest to the time when all the florets wilted.
Cut flowers were kept at 23°C.

Table 4. Effect of sucrose with HQS on anthocyanin concentrations in various cultivars of cut *Eustoma grandiflorum*

Cultivar	Anthocyanin concentration (OD530 nm gFW^{-1})	
	Control (water)	Sucrose + HQS
Azuma-no-ginga	0.40	4.31
Azuma-no-kasumi	0.17	2.52
Piccolo blue	3.65	10.10
Piccolo rose	1.20	4.85

Cut flowers were kept at 23°C.

transported in a cardboard box without water for 1 day, and then they were immersed in tap water and kept at 23°C for 3 days. In spite of unsuitable conditions for cut flowers, the use of sucrose with HQS improved considerably the vase life of cut *Eustoma* flowers. Therefore, the use of sucrose with HQS could become a practical treatment in improving the vase life for consumers as preservative.

4) Snapdragon

The flowers of snapdragon (*Antirrhinum majus* L.) are sensitive to ethylene, and the vase life of the cut flowers is relatively short. Furthermore, most of the buds do not open fully and the color of their petals is slightly expressed[17,24,34].

We examined the effects of sucrose application on the vase life of cut snapdragon flowers[10]. Continuous treatment with sucrose at 25, 50, 75 or 100 g L^{-1} in combination with 200 mg L^{-1} HQS markedly promoted floret opening and extended the vase life of flower spikes (Table 5). In addition, petal color expression was markedly improved by these treatments. The optimum concentration was 50 g L^{-1}. This treatment increased the sugar concentrations of petals and suppressed ethylene production of florets. These results suggest that the effect of sucrose in promoting bud opening and inhibiting flower senescence is probably due to the increase in sugar concentration and inhibition of ethylene synthesis.

Table 5. Effects of various concentrations of sucrose with HQS on the vase life of cut snapdragon flowers

Treatment	Vase life[a] (days)
DW	8.2
0 g L^{-1} sucrose + HQS	10.2
25 g L^{-1} sucrose + HQS	17.4
50 g L^{-1} sucrose + HQS	20.7
75 g L^{-1} sucrose + HQS	17.7
100 g L^{-1} sucrose + HQS	15.0

a): Vase life was determined as the time from harvest to the time when all the florets wilted.
Cut flowers were kept at 23°C.

Conclusion

As described above, treatment with sucrose not only extended the vase life but also promoted flower opening. In addition, sucrose improved the petal color expression. In this paper, I observed that continuous treatment with sucrose is very effective in improving the vase life of cut sweet pea, *Eustoma* and snapdragon flowers. Pulse treatment with sucrose was also effective in cut sweet pea and hybrid *Limonium* flowers. These findings suggest that sugars are effective in improving the vase life of many cut flowers. In addition, sugars are cheap and safe compounds. However, sugars are not much utilized practically in Japan. To keep the quality of cut flowers, the utilization of sugars should be further promoted.

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