Effects of continuous treatments with glucose, sucrose, mannitol, or a combination, on the vase life of cut snapdragon flowers

原著論文

Effects of continuous treatments with glucose, sucrose, mannitol, or a combination, on the vase life of cut snapdragon flowers

Kazuo ICHIMURA [1*] and Tamotsu HISAMATSU [2]

(Received November 2, 2005)

Summary

Glucose, fructose, and mannitol are major soluble carbohydrates in snapdragon (*Antirrhinum majus* L.). We investigated the effects of continuous treatments with 30 or 50 g L^{-1} glucose, 50 g L^{-1} sucrose, or 30 or 50 g L^{-1} mannitol on the vase life of cut snapdragon flowers (i.e., the time until all florets had wilted). Treatments with each of the carbohydrates promoted floret opening and extended vase life. Glucose at 30 g L^{-1} increased the number of open florets most, and mannitol at 50 g L^{-1} extended the vase life most. However, open florets in mannitol treatments were smaller than in glucose or sucrose treatments and their pigmentation was less pronounced than in the glucose and sucrose treatments. The total leaf chlorophyll contents decreased with time, but 30 g L^{-1} glucose mitigated this decrease until the 15th day after harvesting. To reduce the defects of the mannitol treatment, we investigated combinations of mannitol with glucose or sucrose. Treatment with 25 g L^{-1} sucrose plus 25 g L^{-1} mannitol increased the number of open florets and extended vase life more than treatment with 50 g L^{-1} sucrose alone. However, treatment with glucose plus mannitol did not significantly extend vase life compared with glucose alone. White mannitol powder appeared on the surface of florets and leaves in the combined treatments. Overall, treatment with 30 g L^{-1} glucose was most effective in improving vase life.

Key Words: cut flower, glucose, mannitol, snapdragon, sucrose, vase life

[1] *Department of Production, National Institute of Floricultural Science, Fujimoto 2-1, Tsukuba, Ibaraki* 305-8519

[2] *Department of Genetics and Physiology*

* Corresponding author: E-mail, ichimu@affrc.go.jp

Introduction

Snapdragon is a popular cut flower because of its wide range of petal colors and good fragrance. The flowers of snapdragon are sensitive to ethylene (Woltering and van Doorn, 1988; Serek et al., 1995), and the vase life of cut flowers is relatively short (Larsen and Scholes, 1966; Nowak, 1981; Wang et al., 1977). Furthermore, most buds do not open fully, and the petals of the resulting flowers develop little pigmentation (Larsen and Scholes, 1966; Nowak, 1981; Serek et al., 1995; Wang et al., 1977). Silver thiosulfate complex (STS) has been widely used to extend the vase life of snapdragon (Inaba, 1997), but pulse treatment with STS only slightly extends the vase life of cut snapdragons (Nowak, 1981).

Sugars play important roles in plants as substrates for respiration, as cell wall components, and as osmolytes. The addition of sucrose to vase water in combination with antimicrobial compounds markedly promotes bud opening and extends the vase life of many cut flowers, including carnation (Paulin and Jamain, 1982; Koyama and Uda, 1994), rose (Kuiper et al., 1995; Ichimura et al., 1999a), and sweet pea (Ichimura and Hiraya, 1999). Larsen and Scholes (1966) reported that continuous treatment with 2% sucrose was effective in extending the vase life of cut snapdragons. Ichimura and Hisamatsu (1999) previously reported that continuous treatment with 50 g L^{-1} sucrose in combination with 8-hydroxyquinoline sulfate (HQS) markedly improved the vase life of cut snapdragon flowers.

Metabolic sugars, such as glucose, fructose, and sucrose, have been considered to be similarly effective in extending the vase life of cut flowers (Halevy and Mayak, 1981). However, Ketsa and Boonrote (1990) reported that glucose extended the vase life of cut *Dendrobium* flowers more than did sucrose. In a previous study, we also found that continuous treatment with glucose was more effective than continuous treatment with sucrose in extending the vase life of cut rose flowers (Ichimura et al., 2006).

Glucose, fructose, sucrose and mannitol are major soluble carbohydrates in snapdragon, which produces indeterminate inflorescences (Ichimura and Hisamatsu, 1999). Continuous treatment with mannitol suppressed senescence of the spike tips, resulting in the promotion of spike elongation in cut snapdragons (Ichimura et al., 2005). We thus expected that mannitol might usefully extend the vase life of cut snapdragons.

In the present study, we examined the effects of glucose, sucrose, and mannitol, alone and in combination, on the vase life of cut snapdragon flowers.

Materials and Methods

Plant material

Snapdragon (*Antirrhinum majus* L.) cv. Yellow Butterfly was grown under natural daylength conditions in a greenhouse (15℃ minimum and 25℃ maximum temperature) at the National Institute of Floricultural Science (Ano, Mie prefecture) using the standard production method. Flower spikes with three open florets were cut from plants from February to April in 1996.

Carbohydrate treatments and evaluation of the vase life of cut spikes

The spikes were trimmed to 40 cm and placed in a 500-ml beakers (two spikes per beaker) containing 500 mL of 50 g L-$^{-1}$ sucrose, 30 or 50 g L^{-1} glucose, or 30 or 50 g L^{-1} mannitol solution; each solution also contained 200 mg L^{-1} HQS. The molar concentration of 50 g L^{-1} sucrose was almost the same as those of 30 g L^{-1} glucose or mannitol. The spikes

were maintained at 23℃, 70% relative humidity, and 10 μmol m^{-2} s^{-1} irradiance from cool-white fluorescent lamps under a 12-h photoperiod. The numbers of open and wilted florets were counted every day until all florets had wilted. Florets whose petals had fully unfolded were counted as open florets. The vase life of the flower spikes was defined as the time from harvesting to the date when all florets had wilted. In a separate experiment, flower spikes were treated with sucrose at 25 and 40 g L^{-1} in combination with mannitol at 25 and 10 g L^{-1}, respectively, to give a final concentration of 50 g L^{-1}. Flower spikes were also treated with glucose at 15, 24, 25, and 40 g L^{-1} in combination with mannitol at 15, 6, 25, and 10 g L^{-1}, respectively, to give final concentrations of 30 or 50 g L^{-1}.

Chlorophyll determination

Ten leaf disks with diameter of 8.5 mm were randomly collected from the leaves of two cut flowers. The leaf disks were homogenized in 80% acetone. The suspensions were held in the dark for 30 min and then centrifuged at 3,000× g for 10 min. Chlorophyll concentrations in the supernatant were determined using the equation by Arnon (1949), based on the absorbance of the supernatant at 645 and 663 nm.

Identification of mannitol

Any white powder that appeared on the surface of the leaves and florets of the cut flowers were collected and dissolved in distilled water. The components of the resulting solution were separated using an HPLC system (Jasco HPLC, Tokyo, Japan) equipped with a refractive-index detector and a Shodex SUGAR SP0810 column (Showa Denko, Tokyo), which was kept at
80℃ and eluted with water at a flow rate of 0.8 mL min^{-1}. Mannitol was identified based on its retention time (22.5 min).

Results

Effects of carbohydrate treatments on floret opening, vase life and chlorophyll contents

Fig.1 shows the effects of continuous treatments with sucrose, glucose, or mannitol on the number of open florets. In the control, most buds did not open fully, and the open florets became almost whitish. Treatments with any of the three carbohydrates markedly increased the number of open florets, and glucose and mannitol were more effective than sucrose at both concentrations.

All three carbohydrates also significantly increased the vase life of the cut spikes (Table 1, Fig. 2). Treatment with 50 g L^{-1} mannitol was most effective in extending vase life (36.5 days), followed by treatment with 30 g L^{-1} mannitol (30.8 days). However, the open florets of spikes treated with mannitol were smaller than those treated with glucose and sucrose (data not shown), and their petal color became whitish (Fig. 2). In addition, all mannitol-treated spikes exhibited white powder on the surface of florets and leaves within a few days after the start of treatment. This powder was identified as mannitol by HPLC. Glucose at 30 g L^{-1} extended vase life as long as the 30 g L^{-1} mannitol treatment (no significant difference) and significantly longer than 50 g L^{-1} sucrose.

Fig. 3 shows the changes with time in leaf chlorophyll contents in response to treatment with various carbohydrates. In all treatments, the chlorophyll *a* and *b* contents and the total chlorophyll content of the leaves gradually decreased with time. However, sucrose treatment tended to accelerate these decreases, whereas 30 g L^{-1} glucose mitigated these decreases until around the 15th day after harvesting.

Effect of treatment with glucose or sucrose in combination with mannitol on floret opening and vase life

Fig.4 shows the effect of glucose or sucrose in combination with mannitol on the number of open florets. All carbohydrate treatments increased the total number of florets and delayed the decrease in the number of florets compared with the control, but the treatments differed in their effectiveness. The combined treatment with 40 g L^{-1} sucrose and 10 g L^{-1} mannitol slightly delayed the decrease in the number of open florets compared with 50 g L^{-1} sucrose alone. The combined treatment with 25 g L^{-1} sucrose and 25 g L^{-1} mannitol increased the number of open florets significantly more than in either of the other treatments, and considerably delayed the decrease in the number of open florets. The combined treatments with 24 g L^{-1} glucose plus 6 g L^{-1} mannitol and 15 g L^{-1} glucose plus 15 g L^{-1}

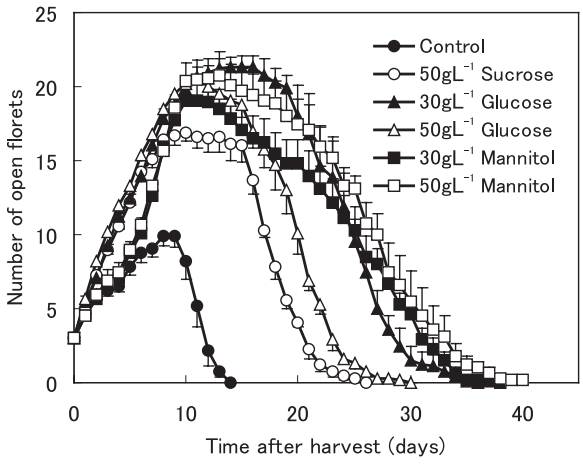

Fig. 1
Changes in the number of open florets in cut snapdragon flowers treated with 30 or 50 g L^{-1} glucose, 50 g L^{-1} sucrose, or 30 or 50 g L^{-1} mannitol. All solutions contained 200 mg L^{-1} HQS. Values represent the means of 5 replications ± SE.

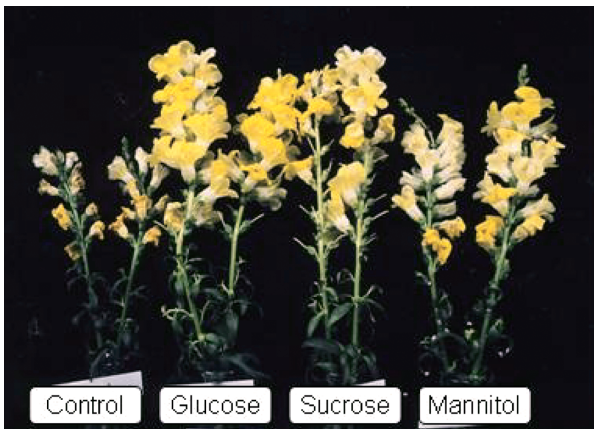

Fig. 2
Effects of treatment with 30 g L^{-1} glucose, 50 g L^{-1} sucrose, or 30 g L^{-1} mannitol on the vase life of cut snapdragon flowers. All solutions contained 200 mg L^{-1} HQS. The photograph was taken 14 days after the start of the carbohydrate treatments. Far left, control; middle left, glucose; middle right, sucrose; far right, mannitol.

Table 1 Effects of glucose, sucrose, and mannitol on the vase life of cut snapdragon flowers.

Treatment	Vase life[z] (days)	Appearance of white powder[y]
Control	13.0±0.3a[x]	
50 g L^{-1} sucrose	22.4±0.3b	
30 g L^{-1} glucose	29.9±1.0cd	
50 g L^{-1} glucose	26.2±0.6bc	
30 g L^{-1} mannitol	30.8±1.0d	*
50 g L^{-1} mannitol	36.5±1.8e	*

[z] Vase life was defined as the time from harvesting to the date when all florets had wilted.
[y] Asterisks represent cut flowers on which white powder (mannitol) appeared.
[x] Values represent the means of 5 replications ± SE. Values followed by the same letters do not differ significantly (P<0.05, Tukey-Kramer multiple-range test).

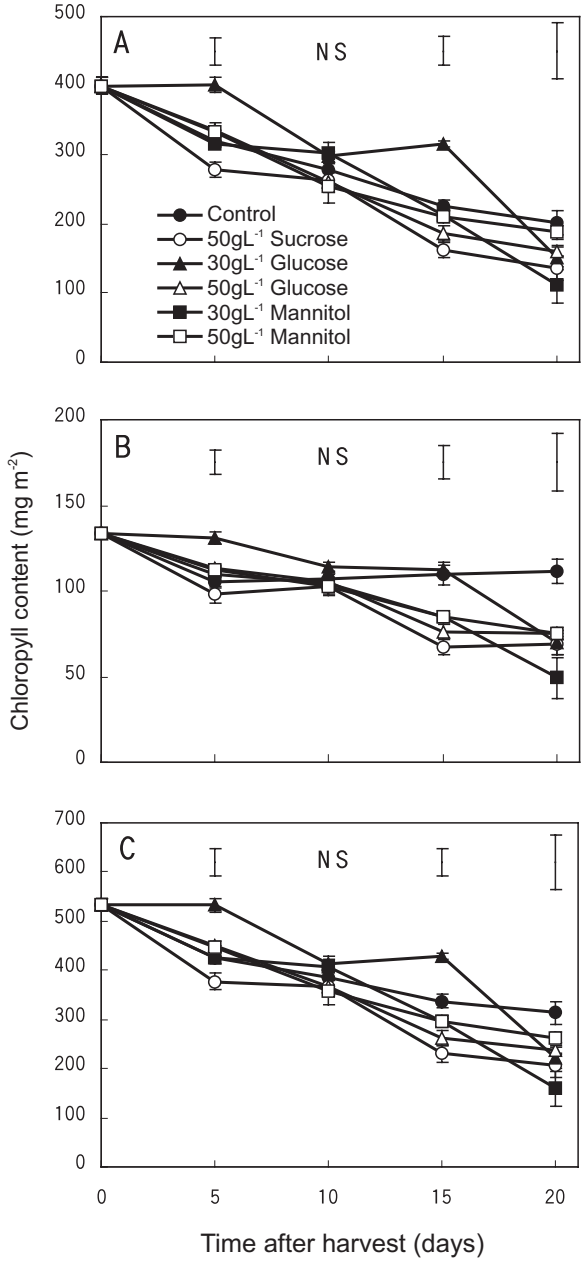

Fig. 3
Changes in the content of (A) chlorophyll *a*, (B) chlorophyll *b* and (C) total chlorophyll contents in leaves in cut snapdragon flowers treated with 30 or 50 g L^{-1} glucose, 50 g L^{-1} sucrose, or 30 or 50 g L^{-1} mannitol. All solutions contained 200 mg L^{-1} HQS. Values represent the means of 3 replications ± SE. Bars indicate the least significant difference (P<0.05, Tukey-Kramer multiple-range test) for each day. NS, nonsignificant.

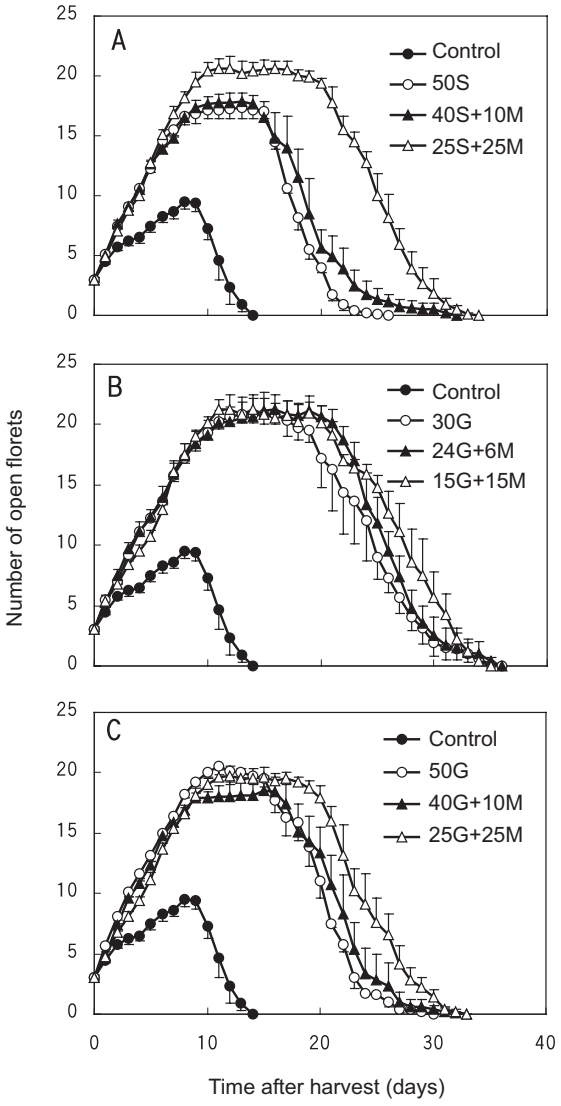

Fig. 4
Changes in the number of open florets in cut snapdragon flowers treated with glucose, sucrose, or mannitol, alone or in various combinations. (A) Flower spikes were treated with 50 g L^{-1} sucrose (50S), 40 g L^{-1} sucrose plus 10 g L^{-1} mannitol (40S+10M), or 25 g L^{-1} sucrose plus 25 g L^{-1} mannitol (25S+25M). (B) Flower spikes were treated with 30 g L^{-1} glucose (30G), 24 g L^{-1} glucose plus 6 g L^{-1} mannitol (24G+ 6M), or 15 g L^{-1} glucose plus 15 g L^{-1} mannitol (15G+15M). (C) Flower spikes were treated with 50 g L^{-1} sucrose (50G), 40 g L^{-1} sucrose plus 10 g L^{-1} mannitol (40G+10M), or 25 g L^{-1} sucrose plus 25 g L^{-1} mannitol (25G+25M). All solutions contained 200 mg L^{-1} HQS. Values represent the means of 4 replications ± SE.

Table 2 Effects of combined treatments with glucose or sucrose plus mannitol on the vase life of cut snapdragon flowers.

Treatment	Vase life[z] (days)	Appearance of white powder[y]
Control	13.0±0.4a[x]	
50 g L^{-1} sucrose	22.6±0.3b	
40 g L^{-1} sucrose + 10 g L^{-1} mannitol	24.9±1.8bc	*
25 g L^{-1} sucrose + 25 g L^{-1} mannitol	30.4±0.8cd	*
30 g L^{-1} glucose	30.1±1.3 cd	
24 g L^{-1} glucose + 6 g L^{-1} mannitol	30.5±1.1cd	*
15 g L^{-1} glucose + 15 g L^{-1} mannitol	32.0±1.2d	*
50 g L^{-1} glucose	26.6±0.5bcd	
40 g L^{-1} glucose + 10 g L^{-1} mannitol	27.3±1.9bcd	*
25 g L^{-1} glucose + 25 g L^{-1} mannitol	30.1±1.6cd	*

[z] Vase life was defined as the time from harvesting to the date when all florets had wilted.
[y] Asterisks represent cut flowers on which white mannitol powder appeared.
[x] Values represent the means of 4 replications ± SE. Values followed by the same letters do not differ significantly ($P<0.05$, Tukey-Kramer multiple-range test).

mannitol slightly delayed the decrease in the number of open florets compared with 30 g L^{-1} glucose alone. Similarly, the combined treatment with 25 g L^{-1} glucose and 25 g L^{-1} mannitol delayed the decrease in number of open florets more than 50 g L^{-1} glucose alone.

The combined treatment with 25 g L^{-1} sucrose and 25 g L^{-1} mannitol extended vase life significantly more than treatment with 50 g L^{-1} of sucrose alone (Table 2). However, combined treatment with glucose and mannitol did not extend vase life significantly more than treatment with glucose alone at all the concentrations we tested. White powder identified as mannitol also appeared on the surface of florets and leaves in all treatments that combined mannitol with glucose or sucrose.

Discussion

Previously, Ichimura and Hisamatsu (1999) reported that the vase life of cut snapdragon flowers was markedly extended by sucrose treatment. Halevy and Mayak (1981) reported that the effect of glucose on the vase life of cut flowers was generally similar to that of sucrose. In the present study, however, we found that treatment with 30 g L^{-1} glucose extended vase life significantly more than treatment with 50 g L^{-1} sucrose (Table 1). We previously reported no significant difference in extending vase life among treatments with 25, 50 and 75 g L^{-1} sucrose (Ichimura and Hisamatsu, 1999). These findings suggest that glucose extends the vase life of cut snapdragons more than sucrose does. Snapdragons have indeterminate inflorescence. We observed that spike tips became brown and wilted after treatment with sucrose, which prevents the opening of florets in the upper part of the spike (data not shown). Previously, Ichimura et al. (2005) reported that sucrose treatment caused a remarkable increase in the sucrose concentration in the spike tips, whereas glucose or mannitol treatment only slightly increased sugar concentrations in these tips. Thus, the observed acceleration of senescence in the spike tip caused by sucrose treatment may result from sugar accumulation in the tip.

Mannitol at 50 g L^{-1} was the most effective in extending the vase life of cut flower spikes (Table 1). However, the size of the open flowers in spikes treated with mannitol was less than in those treated with glucose or sucrose (data not

shown). In addition, white mannitol powder appeared on the surface of florets and leaves after mannitol treatment. This may have resulted from the low solubility of mannitol and may be unacceptable to consumers. Thus, treatment with mannitol alone is not suitable for extending the vase life of cut snapdragons. We further investigated the effect of combined treatment with mannitol plus either glucose or sucrose on vase life. The combination of mannitol and sucrose improved vase life significantly more than sucrose alone, and the effect increased with increasing amounts of mannitol (Table 2, Fig. 4). Combined treatment with mannitol and glucose also improved vase life more than glucose alone, but the difference was not significant. This positive effect can be attributed to inhibition of tip senescence by mannitol. However, white mannitol powder also appeared on the plant surface in all these combined treatments. Thus, combined treatment with mannitol and either glucose or sucrose seems to be an unsuitable choice.

In our study, mannitol delayed the senescence of the spike tips in cut snapdragons. In contrast, mannitol treatment damaged leaves and did not extend the vase life of cut chrysanthemum flowers (Kofranek and Halevy, 1972). Similarly, mannitol treatment inhibited flower opening in cut roses (Ichimura et al., 1999b). However, mannitol was not detected in the flowers, stems, and leaves of these plants (Ichimura et al., 1997, 2000). Thus, the deleterious effects of mannitol in these flowers may result from the absence of an enzyme that can help the plant metabolize mannitol. In higher plants, mannitol is metabolized by mannitol dehydrogenase (Loescher, 1987).

The uptake of sugars often decreases chlorophyll contents in leaves (Yoshida, 2003). In our study, total chlorophyll content in leaves tended to be decrease more rapidly after treatment with sucrose, whereas 30 g L^{-1} glucose suppressed this decrease until around the 15th day after harvesting (Fig. 3). Similarly, sucrose treatment accelerated the yellowing of leaves in cut *Narcissus* flowers (Ichimura and Goto, 2002). Although the reason why glucose was more effective than the other carbohydrates in delaying the decrease in chlorophyll contents remains unclear, glucose may be useful for other cut flowers, including *Narcissus*.

Although pulse treatment with STS has been widely used by snapdragon growers (Inaba, 1997), this treatment only slightly extends the vase life of cut snapdragons (Nowak, 1981). In contrast, treatment with glucose markedly extended the vase life of cut spikes (Tables 1, 2). Thus, treatment with glucose supplemented with a germicide should be useful in extending the vase life of cut snapdragon flowers for consumers.

In conclusion, treatment with mannitol was most effective in extending the vase life of cut snapdragon flowers, but was an unsuitable choice because of its adverse effects on senescence and floret number and size and because it produced a visible white powder on the florets and leaves. Although combined treatment with mannitol and sucrose extended vase life more than sucrose alone, mannitol powder still appeared on the spikes and reduced the ornamental value of the cut flowers. Of the treatments evaluated in the present study, 30 g L^{-1} glucose was most effective at improving the vase life of cut snapdragon flowers without adverse effects.

Literature cited

Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts: Polyphenol oxidases in *Beta vulgaris*. Plant Physiol. 24: 1-15.

Halevy, A. H. and S. Mayak. 1981. Senescence and postharvest physiology of cut flowers, part 2. Hort. Rev. 3 : 59-143.

Ichimura, K. and R. Goto. 2002. Extension of vase life of cut *Narcissus tazetta* var. *chinensis* flowers by combined treatment with STS and gibberellin A_3. J. Jpn. Soc. Hort. Sci. 71:226-230.

Ichimura, K. and T. Hiraya. 1999. Effect of silver thiosulfate complex (STS) in combination with sucrose on the vase life of cut sweet pea flowers. J. Jpn. Soc. Hort. Sci. 68: 23-27.

Ichimura, K. and T. Hisamatsu. 1999. Effects of continuous treatment with sucrose on the vase life, soluble carbohydrate concentrations, and ethylene production of cut snapdragon flowers. J. Jpn. Soc. Hort. Sci. 68: 61-66.

Ichimura, K., K. Kohata, M. Koketsu, Y. Yamaguchi, H. Yamaguchi and K. Suto. 1997. Identification of methyl β-

glucopyranoside and xylose as soluble sugar constituents in roses (*Rosa hybrida* L.). Biosci. Biotechnol. Biochem. 61: 1734-1735.

Ichimura, K., K. Kohata and K. Yamada. 2005. Promotion of spike elongation in cut snapdragons by mannitol. Acta Hortic. 669: 119-124.

Ichimura, K., K. Kohata, Y. Yamaguchi, M. Douzono, H. Ikeda and M. Koketsu. 2000. Identification of L-inositol and scyllitol and their distribution in various organs in chrysanthemum. Biosci. Biotechnol. Biochem. 64: 865-868.

Ichimura, K., K. Kojima and R. Goto. 1999a. Effects of temperature, 8-hydroxyquinoline sulphate and sucrose on the vase life of cut rose flowers. Postharv. Biol. Technol. 15: 33-40.

Ichimura, K., Y. Mukasa, T. Fujiwara, K. Kohata, R. Goto and K. Suto. 1999b. Possible roles of methyl glucoside and *myo*-inositol in the opening of cut rose flowers. Ann Bot 83: 551-557.

Ichimura, K., M. Taguchi and R. Norikoshi. 2006. Extension of the vase life in cut roses by treatment with glucose, isothiazolinonic germicide, citric acid and alminium sulphate solution. JARQ (in press)

Inaba, Z. 1997. Snapdragons. Japan Flower Promotion Center. Manuals for postharvest handling of cut flowers. 68-69. Distribution Systems Research Center. Tokyo. (In Japanese)

Ketsa, S. and A. Boonrote. 1990. Holding solutions for maximizing bud opening and vase-life of *Dendrobium* 'Youppadeewan' flowers. J. Hort. Sci. 65: 41-47.

Kofranek, A. M. and A. H. Halevy. 1972. Conditions for opening cut chrysanthemum flower buds. J. Am. Soc. Hort. Sci. 97: 578-584.

Koyama, Y. and A. Uda. 1994. Effects of temperature, light intensity and sucrose concentrations on bud forcing and carnation flower quality. J. Jpn. Soc. Hort. Sci. 63: 203-209.

Kuiper, D., S. Ribot, H. S. van Reenen and N. Marissen. 1995. The effect of sucrose on the flower bud opening of Madelon cut roses. Sci. Hortic. 60: 325-336.

Larsen, F. E. and J. F. Scholes. 1966. Effects of 8-hydroxyquinoline citrate, N-dimethyl amino succinamic acid, and sucrose on vase-life and spike characteristics of cut snapdragons. Proc. Am. Soc. Hort. Sci. 89: 694-701.

Loescher, W. H. 1987. Physiology and metabolism of sugar alcohols in higher plants. Physiol. Plant. 70: 553-557.

Nowak, J. 1981. Chemical pre-treatment of snapdragon spikes to increase cut-flower longevity. Sci. Hortic. 15: 255-262.

Paulin, A. and C. Jamain. 1982. Development of flowers and changes in various sugars during opening of cut carnations. J. Am. Soc. Hort. Sci. 107: 258-261.

Serek, M., E. C. Sisler and M. S. Reid. 1995. Effects of 1-MCP on the vase life and ethylene response of cut flowers. Plant Growth Regul. 16: 93-97.

Wang, C. Y., J. E. Baker, R. E. Hardenburg and M. Lieberman. 1977. Effects of two analogs of rhizobitoxine and sodium benzoate on senescence of snapdragons. J. Am. Soc. Hort. Sci. 102: 517-520.

Woltering, E. J. and W. G. van Doorn. 1988. Role of ethylene in senescence of petals — morphological and taxonomical relationships. J. Exp. Bot. 39: 1605-1616.

Yoshida, S. 2003. Molecular regulation of leaf senescence. Curr. Opin. Plant Biol. 6 : 79-84.

キンギョソウ切り花の品質保持に及ぼすグルコース，スクロースおよびマンニトール連続処理の影響

市村　一雄・久松　完

和文摘要

キンギョソウの主要な構成糖質であるグルコース（30 および 50g L^{-1}），スクロース（50g L^{-1}）およびマンニトール（30 および 50g L^{-1}）の連続処理がキンギョソウ切り花の品質保持に及ぼす影響を調査した．品質保持期間は収穫後からすべての小花が萎凋するまでの日数とした．処理したすべての糖質はキンギョソウ花穂において，開花小花数を増加し，品質保持期間を延長した．処理した糖質の中で 30g L^{-1} グルコース処理は開花小花数の増加に最も効果が大きかった．50g L^{-1} マンニトール処理は品質保持期間を最も延長した．しかし，マンニトール処理では，開花した小花はグルコースおよびスクロース処理の場合よりも小さく，着色も劣った．葉の総クロロフィル含量は収穫後の時間の経過にともない減少したが，30g L^{-1} グルコース処理は処理開始後 15 日目にはこの減少を抑制した．マンニトール処理の欠点を避けるため，マンニトールとグルコースあるいはスクロースを組合わせた処理が品質保持に及ぼす影響を調べた．25g L^{-1} スクロースと 25g L^{-1} マンニトールを組合わせた処理は 50g L^{-1} スクロース単独処理よりも開花小花数を増加させ，品質保持期間を延長したが，グルコースとマンニトールとの組合わせ処理はグルコース単独処理よりも品質保持期間を有意には延長しなかった．また，すべてのマンニトールを組合わせた処理では，小花および葉の表面からマンニトールが析出した．以上の結果から，今回の試験処理区の中では 30g L^{-1} グルコース単独処理がキンギョソウ切り花の品質保持に最も有効であることが明らかとなった．