Combined Treatment of 8-Hydroxyquinoline and Glucose on Cut Hydrangea Flowers

Niramon Suntipabvivattana[1], Teerisara Jaisao[1] and Yoshikuni Kitamura[2,*]

[1] *School of Agro-Industry, Mae Fah Luang University, Chiangrai, 57100, Thailand*

[2] *Graduate School of Science and Technology, Shinshu University, Minamiminowa, Nagano 399-4598, Japan*

*Corresponding author (E-mail: hyphy281@shinshu-u.ac.jp).

Abstract

The optimum application of cut flower preservative treatments on fresh-stage and antique-stage cut hydrangea flowers was investigated. The vase lives of fresh-stage cut flowers maintained in deionized water (control), in solutions containing 100 mg L^{-1} or 200 mg L^{-1} 8-hydroxyquinoline sulfate (8-HQS), and in a solution containing silver thiosulfate complex (STS) were compared using a hydrangea cultivar 'Endless Summer'. The mean vase life of flowers with 100 mg L^{-1} 8-HQS treatment was significantly longer than that for the control. However, other treatments did not exhibit significant difference from the control. The solutions containing 100 mg L^{-1} or 200 mg L^{-1} 8-HQS were supplemented with 1% and/or 2% glucose, and the fresh-stage cut flowers of 'Endless Summer' were maintained in these prepared solutions. The mean vase life of flowers treated with 100 mg L^{-1} 8-HQS plus 1% glucose treatment was significantly longer than that for flowers under the control 100 mg L^{-1} 8-HQS treatment. The mean vase life of treatment with 200 mg L^{-1} 8-HQS with 1% glucose was significantly longer than for the control 200 mg L^{-1} 8-HQS treatment. The mean vase life of flowers treated with 200 mg L^{-1} 8-HQS with 2% glucose tended toward a longer vase life than that for the control. When the fresh-stage cut flowers of 'Flambeau', 'Grünherz', and 'Miss Hepburn' were maintained in a solution containing 100 mg L^{-1} 8-HQS and 1% glucose, they exhibited significantly longer vase lives than those maintained in deionized water. In conclusion, a solution containing 100 mg L^{-1} 8-HQS and 1% glucose could extend the vase life of fresh-stage cut hydrangea flowers of several cultivars.

Key words: Antique-stage, 8-hydroxyquinoline sulfate (8-HQS), Fresh-stage, glucose, Silver thiosulfate complex (STS).

1. Introduction

Hydrangeas (*Hydrangea* spp.) are popular ornamental plants cultivated in many countries, and demand for cut hydrangea flowers has been increasing in recent years. Hybrids of *H. macrophylla* and *H. serrata* are frequently used for cut flower production. Hydrangea inflorescences are classified into two types based on the arrangement of non-decorative florets and decorative florets: hortensia and lacecap [11,12]. Nearly all hydrangea cultivars in the cut flower market possess hortensia-type inflorescences. In addition, cut hydrangea flowers harvested at two distinct stages are marketed: fresh-stage cut flowers (harvested just after the decorative sepals are completely colored before or during flowering) and antique-stage cut flowers (harvested when the decorative sepals turn green and/or red after flowering) [3].

We have been focusing on the vase lives of cut hydrangea flowers in several studies. In fresh-stage cut hydrangea flowers, defoliation, reduction in the decorative florets, and covering of the inflorescence are effective for extending vase lives. It has been suggested that these treatments extend vase lives by

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suppressing transpiration of the cut flowers[6, 9]. In addition, transpiration of non-decorative floral organs regulates the vase lives of fresh-stage cut hydrangea flowers[5]. Further, the harvest stage is a major factor for the vase lives of the cut hydrangea flowers, and the antique-stage cut flowers often exhibit longer vase lives than the fresh-stage cut flowers[7].

Many studies on the application of cut flower preservative agents such as surfactant, biocide, and other supplements have been reported[1, 2, 8]. A report by Ku and Cho[8] proposed that the application of sucrose with 8-hydroxyquinoline sulfate (8-HQS) was an optimum cut hydrangea flower preservative treatment. Kazaz *et al.*[2] reported that a solution containing 200 mg L^{-1} 8-HQS could extend the vase lives of cut hydrangea flowers. However, to the best of our knowledge, no report has focused on the combined treatment of 8-hydroxyquinoline sulfate (8-HQS), glucose, and/or silver thiosulfate complex (STS). It is well known that the 8-HQS, glucose, and STS are applied as a germicide, an energy supplement for the cut flowers, and an inhibitor of ethylene action, respectively. In the present study, we investigated the effects of these cut flower preservative agents on the vase lives of cut hydrangea flowers. From the results, an optimum combined application of the 8-HQS and glucose is proposed.

2. Materials and Methods

2.1 Plant materials

Five hydrangea cultivars, 'Endless Summer', 'Flambeau', 'Grünherz', 'Magical Diamond', and 'Miss Hepburn' were used for the studies. 'Endless Summer', 'Flambeau', 'Grünherz', and 'Miss Hepburn' are cultivars used as garden shrubs, but we often find they are also used for cut flower production. 'Magical Diamond' is a cultivar bred for cut flower production in the Netherlands. These five cultivars are hybrids between or among *H. macrophylla* and *H. serrata*. 'Endless Summer' was purchased from a nursery. 'Magical Diamond' was obtained as cuttings from a farmer in 2010. The rest of the cultivars were obtained as cuttings from the Kyoto University experimental farm in May 2010. At the Shinshu University experimental farm, all plants were grown in 32.5-cm-diameter pots filled with 8 L medium consisting of 75% Metro Mix 250 (SunGro Horticulture, Agawam, MA, USA) and 25% vermiculite (v/v) (Asahi Kogyo, Okayama, Japan) from December to March in a greenhouse maintained above 0 °C. Plants were grown under full sunlight from October to May, and under 50% sunlight from June to September. To set 50% sunlight condition, a SUNSUN screen (SSC 50; Nihon Widecloth Co, Ltd., Osaka, Japan) was used.

2.2 Harvest, preparation, and vase life of cut flowers

Fresh-stage cut hydrangea flowers with approximately 50-cm stems were harvested just after approximately 80% of the non-decorative florets in the inflorescence entered anthesis. Antique-stage cut hydrangea flowers with approximately 50-cm stems were harvested just after approximately 80% of the decorative florets in the inflorescence became green-colored. Inflorescences considered to have almost identical numbers of decorative florets were harvested from each cultivar or harvest stage. All cut flowers were defoliated just after harvest. Leaving 40-cm stems, the end of the cut flower stem was recut under deionized water just after harvest.

In experiments 1, 2, and 3, all cut flowers were kept in plastic bottles filled with 1 L of deionized water or appropriate solutions. Mean vase life was calculated from vase life of each cut flower maintained in the bottle. In experiment 4, ELF containers, containers typically used for cut flower transport in many countries, were used for cut flower maintenance. Each of the three cut flowers was maintained in an ELF container filled with 1 L of deionized water or appropriate solutions, and three ELF containers with cut flowers were prepared for each cultivar. Mean vase life of three cut flowers was calculated for each container. A final score of mean vase life was calculated from the mean vase lives obtained from the three containers. Water or solution was added appropriately; recutting of the stem end and water or solution

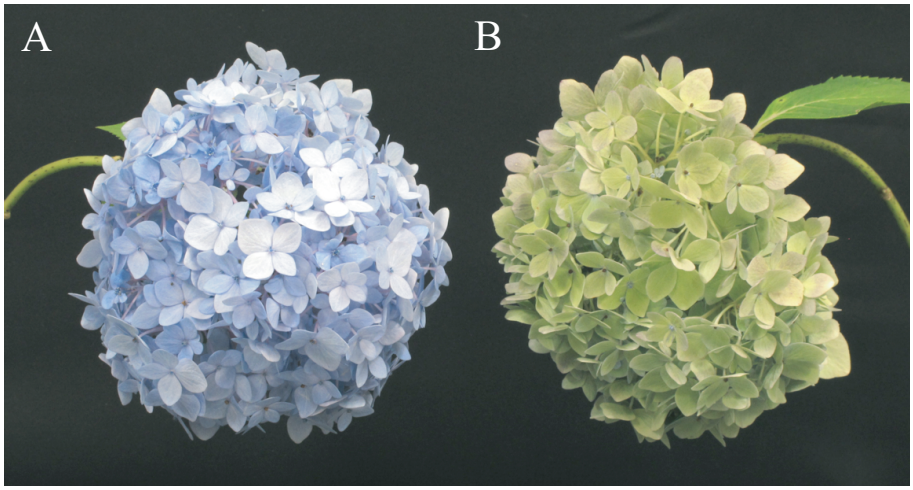

Fig. 1 Two distinct harvest stages of cut hydrangea flowers.

(A) Fresh-stage cut flowers (harvested just after the decorative sepals are completely colored before or during flowering). (B) Antique-stage cut flowers (harvested when the decorative sepals turn green and/or red after flowering).

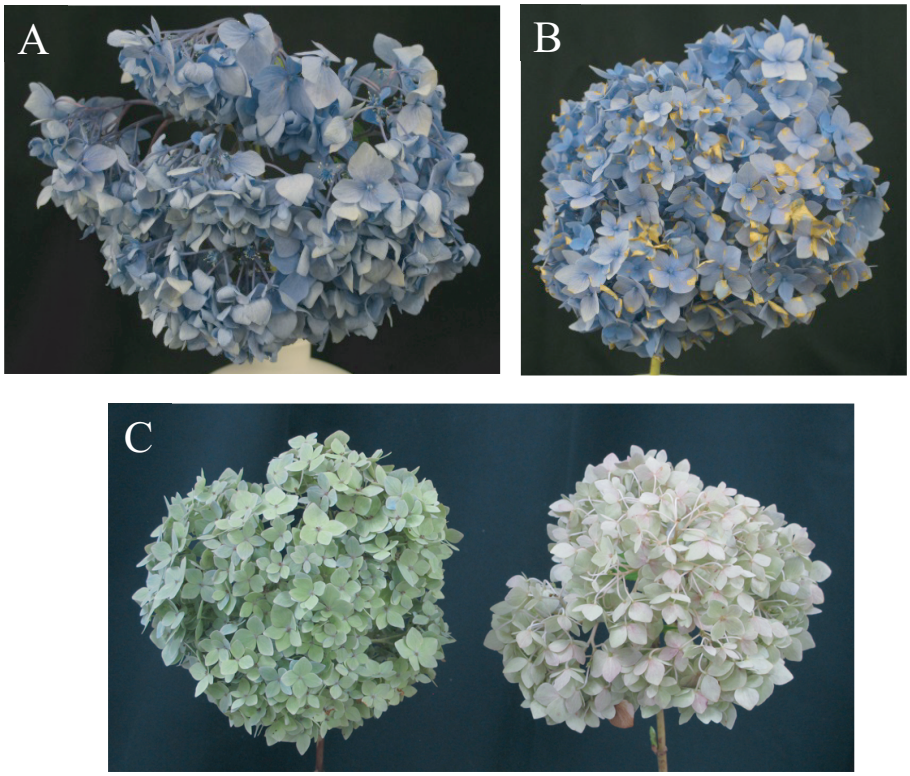

Fig. 2 Appearances of fresh-stage and antique-stage cut flowers at the end of their vase lives.

(A) Wilting of a fresh-stage cut flower with shrinking of decorative sepals. (B) Browning of decorative sepals. (C) Yellowing of decorative sepals observed in antique-stage cut flowers (right). The inflorescence on the left side indicates a healthy inflorescence of the antique-stage cut hydrangea flower.

exchange were not conducted during the study. Cut flowers were placed in an environment-controlled room at 25 ± 2°C and 50 ± 5% relative humidity, and were maintained under 12-h photoperiods at a light intensity of 10 μmol m^{-2} s^{-1} provided by daylight fluorescent tubes (FL40SSN/37; Toshiba Lighting and Technology Co., Yokosuka, Japan).

Vase life of a fresh-stage cut flower was terminated when withering, and/or sepal browning became apparent on approximately 80% of decorative florets in an inflorescence based on daily observations (Fig.

2A, B). In addition to these above-mentioned symptoms, yellowing of the decorative sepals and/or sepal desiccation were used as symptoms that indicate the end of the vase life of an antique-stage cut flower (Fig. 2C). Our previous study showed that the stem diameters are almost identical between cut flowers bearing similar numbers of decorative florets[2]. Therefore, the stem diameters of cut flowers were not investigated in this study.

2.3 Vase life of the fresh-stage cut flower maintained with different cut flower preservative reagents (experiment 1)

The differences in the vase lives of the cut flowers maintained with different cut flower preservative reagents were compared using 'Endless Summer'. The fresh-stage cut flowers were maintained in deionized water as a control, in solutions containing 100 mg L^{-1} or 200 mg L^{-1} 8-HQS, and in a solution containing STS. 8-HQS was purchased as a reagent (Nakarai Tesque Inc., Kyoto, Japan). STS was purchased as a cut flower preservative solution (K–20C; Chrysal Japan Co. Ltd., Osaka, Japan), and was used as a 1000^{-1} diluted solution according to the manufacture's instruction. During June 2017, five cut flowers were prepared for each of three treatments and the control, and vase life was determined as already described. Data collected for vase life were analyzed using Tukey's multiple range test.

2.4 Vase life of the fresh-stage cut flower maintained with 8-HQS and glucose (experiment 2)

For experiment 2, the 8-HQS treatments were combined with glucose. Solutions containing 100 mg L^{-1} 8-HQS with 1% glucose, containing 200 mg L^{-1} 8-HQS with 1% glucose, and containing 200 mg L^{-1} 8-HQS with 2% glucose were prepared, and fresh-stage cut flowers of 'Endless Summer' were maintained in these solutions. Vase lives of cut flowers maintained in the solution containing 100 mg L^{-1} or 200 mg L^{-1} 8-HQS in experiment 1 were used as controls. During June 2017, four or five cut flowers were prepared for each of the three treatments, and vase life was determined as already described. Differences of vase lives for treatment with 200 mg L^{-1} 8-HQS and 200 mg L^{-1} 8-HQS with 1% glucose were analyzed using Welch's *t*-test. Differences among the vase lives for treatment with 200 mg L^{-1} 8-HQS, 200 mg L^{-1} 8-HQS with 1% glucose, and 200 mg L^{-1} 8-HQS with 2% glucose treatments were analyzed using Tukey's multiple range test.

2.5 Vase life of the antique-stage cut flower maintained with 8-HQS and glucose (experiment 3)

For experiment 3, the effectiveness of the combined treatment of 8-HQS and glucose was verified using antique-stage cut hydrangea flowers. Solutions containing 100 mg L^{-1} 8-HQS with 1% glucose and containing 100 mg L^{-1} 8-HQS with 2% glucose were prepared, and antique-stage cut flowers of 'Endless Summer' were maintained in the prepared solutions. Vase life of the cut flower maintained in a solution containing 100 mg L^{-1} 8-HQS was used as a control. During July 2017, four or five cut flowers were prepared for each of two treatments and the control, and vase life was determined as already described. Differences among the treatments and the control were analyzed using Tukey's multiple range test.

2.6 Application of the optimized cut hydrangea flower preservative solution (experiment 4)

In experiment 4, the optimum application of cut flower preservatives that derived from experiments 1, 2, and 3 was verified using fresh-stage cut flowers of four hydrangea cultivars. The fresh-stage cut flowers of 'Flambeau', 'Grünherz', 'Magical Diamond', and 'Miss Hepburn' were maintained in solutions containing the 100 mg L^{-1} 8-HQS and 1% glucose. Aiming for comparing this with cut flowers without any treatment, cut flowers maintained in deionized water were used for the vase life control. During June 2018, nine cut flowers were prepared for the treatment and nine for the control, and vase life was determined as already described. Data collected for vase lives with the treatment and for the control were analyzed using Welch's

t-test for each cultivar.

3. Results

3.1 Vase life of fresh-stage cut flowers maintained with different cut flower preservative reagents (experiment 1)

The mean vase life of cut flowers treated with 100 mg L^{-1} 8-HQS was 14 days, and this was significantly longer than that for the control cut flowers, which exhibited a mean vase life of 6 days (Fig. 3). The mean vase life of cut flowers treated with 200 mg L^{-1} 8-HQS was 11 days, which showed a tendency to be longer than that for the control. However, no significant difference was detected. The mean vase life of cut flowers with STS treatment was 6 days, and this was not different from that for the control.

3.2 Vase life of fresh-stage cut flowers maintained with 8-HQS and glucose (experiment 2)

The mean vase life of cut flowers treated with 100 mg L^{-1} 8-HQS with 1% glucose treatment was 26 days, which was significantly longer than that for the control 100 mg L^{-1} 8-HQS treatment, which exhibited a mean vase life of 14 days (Fig. 4A). The mean vase life of cut flowers treated with 200 mg L^{-1} 8-HQS with 1% glucose treatment was 26 days, which was significantly longer than that for the control 200 mg L^{-1} 8-HQS treatment, which exhibited a mean vase life of 11 days (Fig. 4B). The mean vase life of cut flowers treated with 200 mg L^{-1} 8-HQS with 2% glucose treatment was 20 days, which showed a tendency toward a longer vase life than that for the control. There was no significant difference in vase lives among the treatments with 100 mg L^{-1} 8-HQS with 1% glucose, 200 mg L^{-1} 8-HQS with 1% glucose, and 200 mg L^{-1} 8-HQS with 2% glucose (data not shown).

3.3 Vase life of antique-stage cut flowers maintained with 8-HQS and glucose (experiment 3)

Mean vase lives of antique-stage cut flowers with two different treatments and the control ranged from 33 to 38 days, however no significant difference was found among them (Fig. 5). Mean vase life of antique-stage cut flowers with the control 100 mg L^{-1} 8-HQS treatment was 38 days and was much longer than that for the fresh-stage cut flowers maintained in the solution containing 100 mg L^{-1} 8-HQS. This result

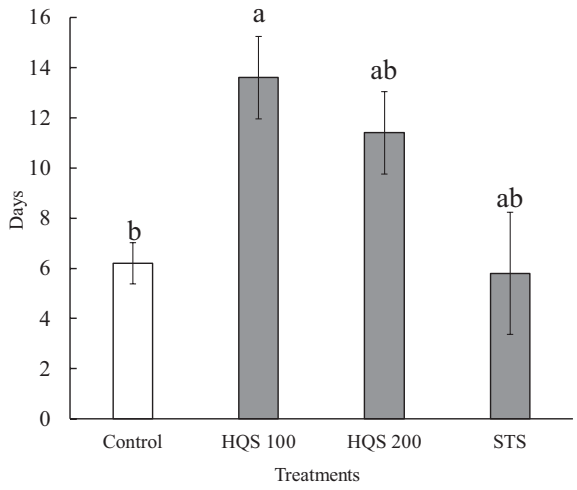

Fig. 3 Vase life of the fresh-stage cut flower maintained with distinct cut flower preservative reagents.

Control: maintained in deionized water. HQS 100: maintained in a solution containing 100 mg L^{-1} 8-HQS. HQS 200: maintained in a solution containing 200 mg L^{-1} 8-HQS. STS: maintained in an STS solution. STS was purchased as a cut flower preservative solution (K-20 C; Chrysal Japan Co. Ltd.,Osaka, Japan), and was used as a 1000^{-1} diluted solution. Bars indicate SE (n = 5). Different letters indicate significant difference at $P < 0.05$ by Tukey's multiple range test.

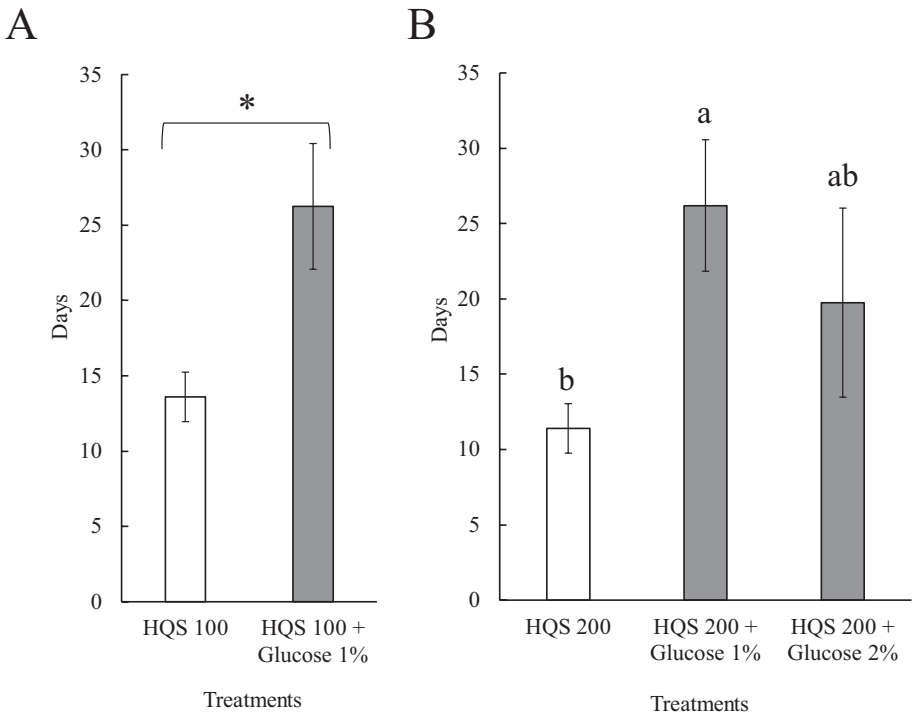

Fig. 4 Vase life of the fresh-stage cut flower maintained in the solution containing 8-HQS and glucose.

(A) HQS 100: maintained in a solution containing 100 mg L^{-1} 8-HQS. HQS 100 + Glucose 1%: maintained in a solution containing 100 mg L^{-1} 8-HQS and 1% glucose. (B) HQS 200: maintained in a solution containing 200 mg L^{-1} 8-HQS. HQS 200 + Glucose 1%: maintained in a solution containing 200 mg L^{-1} 8-HQS and 1% glucose. HQS 200 + Glucose 2%: maintained in a solution containing 200 mg L^{-1} 8-HQS and 2% glucose. Bars indicate SE (n = 4 or 5). * indicates significant difference at $P < 0.05$ by Welch's *t*-test. Different letters indicate significant difference at $P < 0.05$ by Tukey's multiple range test.

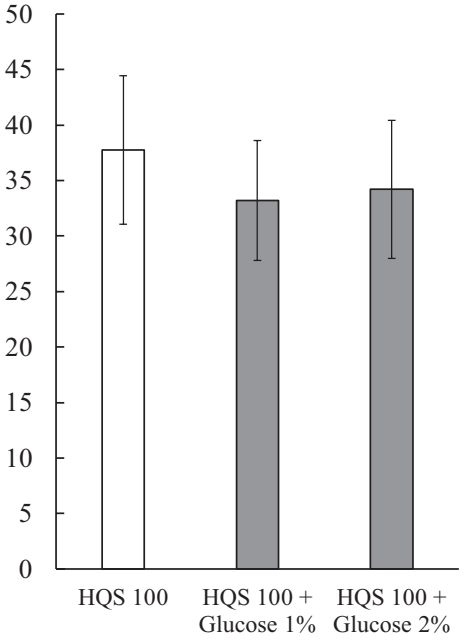

Fig. 5 Vase life of the antique-stage cut flowers maintained in a solution of 8-HQS with glucose.

HQS 100: maintained in a solution containing 100 mg L^{-1} 8-HQS. HQS 100 + Glucose 1%: maintained in a solution containing 100 mg L^{-1} 8-HQS and 1% glucose. HQS 100 + Glucose 2%: maintained in a solution containing 100 mg L^{-1} 8-HQS and 2% glucose. Bars indicate SE (n = 4 or 5). No significant difference was observed among the treatments or control.

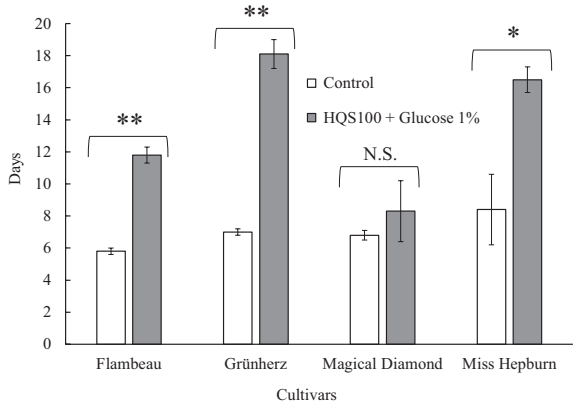

Fig. 6 Vase lives of the fresh-stage cut flowers of several hydrangea cultivars maintained in a solution containing 100 mg L^{-1} 8-HQS and 1% glucose.

Control: maintained in deionized water. HQS 100 + Glucose 1%: maintained in a solution containing 100 mg L^{-1} 8-HQS and 1% glucose. Three ELF containers, each holding three cut flowers, were prepared for each cultivar. Mean vase life for three cut flowers was calculated for each container. Then a final score of mean vase life was calculated from the mean vase lives obtained from three containers. Bars indicate SE (n = 3). * and ** indicate significant difference at $P < 0.05$ and < 0.01, respectively, by Welch's *t*-test between the control and treatment in a cultivar.

supported our previous study, which reported longer vase lives for antique-stage cut hydrangea flowers than that for fresh-stage cut hydrangea flowers[7].

3.4 Application of the optimized cut hydrangea flower preservative solution (experiment 4)

The results obtained from experiments 1, 2, and 3 indicated that the solution containing 100 mg L^{-1} 8-HQS with 1% glucose was an optimum cut flower preservative solution for fresh-stage cut hydrangea flowers. Therefore, the solution was tested for the fresh-stage cut flowers of several hydrangea cultivars. When the fresh-stage cut hydrangea flowers of 'Flambeau', 'Grünherz', and 'Miss Hepburn' were maintained in a solution containing 100 mg L^{-1} 8-HQS with 1% glucose, the mean vase lives of these cultivars were 12, 18, and 17 days, respectively. These were significantly longer than those for the control, which were 6, 7, and 8 days, respectively (Fig. 6). However, 'Magical Diamond' was an exception, whose mean vase lives of flowers treated with 100 mg L^{-1} 8-HQS with 1% glucose and control were 7 and 8 days, respectively.

4. Discussion

STS application had no effect for vase life extension in cut hydrangea flowers. STS is an inhibitor of ethylene action. Kitamura and Ueno[6] reported that elimination of secondary inflorescence extended the vase life of fresh-stage cut hydrangea flowers by decreasing transpiration from the cut flowers. The report suggested that the wounding of inflorescence has little negative effect on the vase life of hydrangeas. Considering this in conjunction with the results of present study, ethylene would not contribute to the short vase life of the fresh-stage cut hydrangea flowers.

In accordance with the study reported by Kazaz *et al.*[2], 8-HQS application extended the vase life of fresh-stage cut hydrangea flower. Kazaz *et al.*[2] concluded that 200 mg L^{-1} 8-HQS was an optimum concentration for preservative solution for fresh-stage cut hydrangea flowers. However, in the present study, the solution containing 100 mg L^{-1} 8-HQS extended the vase life as well. A candidate factor to explain the difference in results between the present study and those of Kazaz *et al.*[2] might be the hydrangea cultivars used. 'Endless Summer', the cultivar used in the present study, often has a very short vase life[3]. The relatively lower 8-HQS concentration might be appropriate for maintaining the hydrangea cultivar that have shorter vase life. Unfortunately, we do not have the cultivars used by Kazaz *et al.*[2] and could not verify this hypothesis.

Cut flower preservative reagents increase the shipping cost of cut flowers, and 8-HQS is one of the

expensive cut flower preservative reagents. Farmers have been trying to reduce the production and shipping costs of cut flowers for years, and the amounts of reagents to be used should be minimized. Thus, it should be noted that the vase live extension performance of the solution containing 100 mg L^{-1} 8-HQS showed a possibility for cost reduction in the shipping of cut hydrangea flowers because of a lower concentration of 8-HQS than was proposed by Kanaz *et al.*[2].

It is well known that saccharide treatment supplies the energy and extends the vase life of cut flowers of many plant species. Ku and Cho[8] reported that a solution containing sucrose and 8-HQS extended the vase life of the cut hydrangea flowers more than the single use of sucrose or 8-HQS. In the present study, glucose application with 8-HQS treatment also extended the vase lives of cut hydrangea flowers more than the single use of 8-HQS. Nakajima[10] reported that cut dahlia flowers contained glucose and fructose as well as sucrose. Further, they reported that the glucose and fructose contents in them were correlated with the vase life of cut flowers but sucrose content was not. Glucose may also play an important role in maintaining cut hydrangea flowers after their harvest. Kitamura *et al.*[7] previously reported the differentiations of cells with secondary cell walls in veins of decorative sepals of hydrangea after flowering. The secondary cell wall consists of lignin, cellulose, and hemicellulose, and cellulose is a polymer of glucose. Thus, secondary cell wall thickening would consume a great deal of glucose in a cut hydrangea flower. The antique-stage cut hydrangea flowers are harvested after the thickening of the secondary cell wall[7], and 100 mg L^{-1} 8-HQS with 1% glucose treatment could not extend the vase lives of cut flowers of that stage. This result and the long vase life of antique-stage cut hydrangea flowers in the control also supported the already-stated hypothesis.

Treatment with 100 mg L^{-1} 8-HQS with 1% glucose could efficiently extend the vase lives of three hydrangea cultivars. However, the vase lives of the cultivars were shorter than that of 'Endless Summer'. This could be due to the difference in the evaluation of the vase life between experiment 2 and 4. Specifically, a cut flower was maintained in a plastic bottle filled with 1 L preservative solution in experiment 2, whereas three cut flowers were maintained in an ELF container filled with 1 L preservative solution in experiment 4. Deterioration of the preservative solution might be promoted because of the maintenance of more cut flowers in experiment 4. A cultivar difference in the extension of vase life of treatment with 100 mg L^{-1} 8-HQS with 1% glucose was also observed. In contrast with the present study, in which five hydrangea cultivars were studied, some studies that evaluated the 8-HQS and/or saccharide treatment each studied one or two hydrangea cultivars and reported no cultivar difference[2, 8]. Hence, cultivar difference should be studied for the previously reported treatments for cut hydrangea flower preservation.

In conclusion, the solution containing 100 mg L^{-1} 8-HQS with 1% glucose could extend the vase life of the fresh-stage cut hydrangea flowers in several cultivars. However, the solution did not prolong the vase lives of one of the hydrangea cultivars and of the antique-stage cut hydrangea flowers.

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