Vase Life and Quality of Cut Flower by NaOCl and Sucrose Treatment as Wet Harvesting Solution in Standard Chrysanthemum 'Baekma'

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ABSTRACT

This study was carried out to examine the effective wet harvesting solution for development of wet distribution system in standard chrysanthemum (*Dendranthema grandiflorum*) 'Baekma'. The cut flowers were treated immediately in floral preservative solutions or dry condition after harvesting, and then the effects on quality of cut flower were compared. Also, we investigated the effects of NaOCl and sucrose on vase life and quality of cut flower. When the cut flowers were treated immediately in tap water, Chrysal OVB, Floralife, Hiflora solutions after harvesting, flower diameter and fresh weight of cut flower increased compared to dry condition treatment. In single treatment of 100 mg·L⁻¹ NaOCl as wet harvesting solution, flower diameter and fresh weight of cut flower increased more than other treatments, and vase life was prolonged to 1.5 days than control. But, flower diameter and fresh weight of cut flower decreased in 0 or 200 mg·L⁻¹ NaOCl. When the cut flowers were treated in combination solution of 100 mg·L⁻¹ NaOCl and 0.1% sucrose, the flower diameter was the largest by 9.8 cm, and fresh weight of cut flower was maintained the highest in holding solution. On the other hand, flower diameter and fresh weight of cut flower were lowest in combination solution of 100 mg·L⁻¹ NaOCl and 2.5% sucrose. There was no difference in vase life between treatments mixed with NaOCl and sucrose. Therefore, it was suggested that treatment mixed with 100 mg·L⁻¹ NaOCl and 0.1% sucrose as wet harvesting solution was the most effective for vase life and quality of cut flower in standard chrysanthemum 'Baekma'.

Keywords: *Dendranthema grandiflorum*, flower diameter, fresh weight, wet distribution system

Introduction

Most flowering plants are used for cut flowers, potted flowers and bedding flowers, and the cultivated area of cut flowers in 2015 among all flowering plants in Korea is 1,459ha (25.0%), which is wider than that of potted flowers, and the production amount is as high as 217.409 billion KRW (34.3%). Moreover, out of the total flowering plants exports \$26.434 million in 2016, cut flowers took up \$19.330 million (73.1%), which shows their importance (KATI, 2017). In 2015, cut chrysanthemums had the cultivated area of 374.2ha (27.4%) and output of 155.512 million plants (30.3%), indicating that they take up the biggest portion of all cut flowers (MAFRA, 2017).

Unlike potted flowers, cut flowers are distributed without roots after harvest, and thus it is very important to maintain

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quality. The quality of cut flowers is determined by quantitative characteristics like stalk length, weight, leaf number, and size of flower and leaf; qualitative characteristics like disease, physical injury, and flower conditions; and sensible characteristics like appearance, flower color, fragrance, and texture. However, post-harvest quality assessment of cut flowers can be determined by the life, quality or freshness maintenance of cut flowers (Son, 1995).

To maintain vase life and quality of cut flowers, there must be proper management at the levels of producers, distribution and consumers. At the producer level, cut flowers are harvested in the right time and shipped after pretreatment (Seo et al., 2005). Vase life of cut flowers was extended and there was effect on fresh weight, absorbed amount and moisture balance when the following pretreatment solutions were used: 0.002 mL·L⁻¹ Vital oxide (Lee et al., 2016) or 0.5 mM STS(silver thiosulfate) + 700 mg·L⁻¹ aluminum sulfate + 1% glucose (Yoo et al., 2003) for roses, 3% sucrose + 200 mg·L⁻¹ HQC + 50 mg·L⁻¹ AgNO₃ + 50 mg·L⁻¹ GA₃ (Hwang et al., 2007) for lilies, 500 nL 1-MCP (1-methylcyclopropene) or 1mL STS (Kim et al., 2009; Kim et al, 2010) for irises, and 200 mg·L⁻¹ NaOCl + 0.1% sucrose + 20 mg·L⁻¹ BA (Yoo et al., 2016) for cut chrysanthemums. As such, using pretreatment solutions at the level of producers is effective for extending the life and maintaining the quality of cut flowers, but it also cause deterioration of quality as farms leave the cut flowers for hours in the greenhouse or shed from right after harvest to pretreatment. Kim and Lee (2006) soaked the rose 'Rote Rose' in water immediately after harvest and discovered that the vase life increased by 14.3% compared to the flowers left for 15 minutes in the greenhouse, and the flower diameter decreased as the neglected time increased.

Studies were conducted on wet harvesting solutions in the distribution process of cut flowers, and it was found that in the case of cut lilies for export, wet treatment with floral preservative like Chrysal RVB or ground water extends vase life more than the dry method before transporting to the exporting company right after harvest, while also improving the bending of the cut flowers (Lee and Kim, 2016). Moreover, wet treatment in transport by putting cut lilies in water in simulated export ended up extending the vase life for 2 days and maintaining the freshness than the dry method (Lim et al., 2016). However, there is almost no research on wet harvesting solutions, which raises the need for research on wet harvesting solutions to maintain the quality of cut flowers immediately after harvest or during local and global distribution processes.

Therefore, this study determines an effective wet harvesting solution to develop a wet distribution system for standard chrysanthemum 'Baekma', the export of which is recently increasing to Japan. This study compared the effects on the quality of cut flowers between dry condition after harvesting and treatment in cut flower life extender solution. It also determined the effects on the quality and vase life of cut flowers after NaOCl and sucrose treatment that has been proved effective as chrysanthemum pretreatment solution.

Research Method

Quality and vase life of cut flower by dry condition and preservative chemicals treatment

This experiment used standard chrysanthemum 'Baekma' harvested in a chrysanthemum farm located in Jeonju, Jeonbuk. Stage three cut flowers with the bud diameter of 2.0±0.2 cm (Yoo and Roh, 2015a) were harvested on July 25 and kept in dry condition in a greenhouse for one hour, and others were put in 4 wet harvesting solutions such as 3 mL·L⁻¹ Chysal OVB (Chrysal International B.V., Nederland), 10 mL·L⁻¹ Floralife (Floralife Inc., USA), 10 mL·L⁻¹ Hiflora (Palace Chemical Co Ltd, Japan) that are distributed as preservative chemicals, as well as tap water (pH 6.3, EC 0.1 dS·m⁻¹) immediately after harvesting. They were transported to Mokpo National University for two hours with a 5°C refrigerator car, still kept in the solutions. Then the cut flowers were cut into 80cm to investigate the diameter and fresh weight, and

were packed in cardboard boxes (100 flowers in each box). Considering the transportation time from Korea to the Japanese importer, it was put under simulated shipping for 4 days at a 5°C cold chamber, after which the flower diameter and fresh weight were examined. Then, the lower part of the flowers were cut again by 10 cm, after which they were put into a square vase holding 50 mg·L⁻¹ NaOCl solution, 5 flowers in each vase in 3 repetitions. For quality assessment of cut flowers, the fresh weight, flower diameter and vase life were examined in a constant temperature room in 20°C and 50% relative humidity, according to the method by Yoo and Roh (2015a).

Quality and vase life of cut flower by NaOCl treatment as a wet harvesting solution

This experiment used standard chrysanthemum ‘Baekma’ harvested in a chrysanthemum farm located in Jeonju, Jeonbuk. Stage three cut flowers were harvested on August 5, right after which they were put in 0, 12.5, 25, 50, 100, 200 mg·L⁻¹ NaOCl (Daejung Chemicals & Metals Co Ltd., Korea) solutions and transported to Mokpo National University with a 5°C refrigerator car. After that the same procedures were applied as Experiment 1.

Quality and vase life of cut flower by mixed use of NaOCl and sucrose treatment as a wet harvesting solution

This experiment used standard chrysanthemum ‘Baekma’ harvested in a chrysanthemum farm located in Jeonju, Jeonbuk. Stage three cut flowers were harvested on August 28, right after which they were put in NaOCl 100 mg·L⁻¹ mixed with sucrose 0, 0.02, 0.1, 0.5, 2.5% and transported to Mokpo National University with a 5°C refrigerator car. After that the same procedures were applied as Experiment 1.

Results and Discussions

Quality and vase life of cut flower by dry condition and preservative chemicals treatment

Standard chrysanthemum ‘Baekma’ was left in the greenhouse for 1 hour after harvesting for dry treatment, and put in solutions immediately after harvesting for wet treatment using tap water and preservative chemicals distributed in the market such as Chrysal OVB, Hiflora, Floralife. Table 1 shows the result of examining the changes in flower diameter and fresh weight after simulated shipping for 4 days at 5°C. The flower diameter slightly decreased to 97.4~99.5% overall, but showed no statistical difference. However, fresh weight showed the biggest decrease to 91.5% in dry treatment, and some

Table 1. Changes in flower diameter and fresh weight of cut flower after simulated shipping for 4 days at 5°C by dry and wet harvesting solution treatment in standard chrysanthemum ‘Baekma’.

Treatment	% of initials	
	Flower diameter	Fresh weight
Dry	97.4 a	91.5 b ^z
Tap water	97.9 a	96.2 a
Chrysal OVB	98.3 a	96.6 a
Hiflora	97.7 a	95.8 a
Floralife	99.5 a	95.2 a

^zMean separation within column by Duncan’s multiple range test at 5% level.

leaves wilted (Fig. 1). On the other hand, wet treatments using tap water and products distributed in the market showed no statistical difference.

Standard chrysanthemum 'Baekma' was left in the greenhouse for 1 hour after harvesting for dry treatment, and put in solutions immediately after harvesting for wet treatment using tap water and cut flower life extenders distributed in the market such as Chrysal OVB, Hiflora, Floralife. They were put in preservative solutions after simulated shipping for 4 days at 5°C, and the quality and vase life of the cut flowers were examined every 2 days. The flower diameter constantly increased until Day 22 in the preservative solutions, and it was smallest in Hiflora, while there was no statistical difference in those treated with tap water, Chrysal, and Floralife (Fig. 2A). The fresh weight was maintained at the lowest in dry treatment, while it was relatively high in Floralife (Fig. 2B). The life was shortest in dry treatment (18.6 days), and showed a statistical difference from other treatments. There was no statistical difference between tap water and other solutions, with the vase life ranging from 19.9 to 20.7 days (Table 2).

Choi et al. (2014) claimed that Chrysal SVB treatment during shipping in the process of exporting oriental lily 'Siberia' is not effective in maintaining the freshness of cut flowers. On the other hand, Lim et al. (2016) argued that Chrysal SVB or AVB treatment as wet solution extends the vase life of cut flowers for 2 days in simulated shipping of oriental lily 'Medusa'. Moreover, Lee and Kim (2016) also discovered that using Chrysal SVB as a wet harvesting solution for

Figure 1. Cut flower quality after simulated shipping for 4 days at 5°C by dry (left) and wet harvesting solution 'Floralife' (right) treatment in standard chrysanthemum 'Baekma'. Arrows indicate the wilting leaves.

Figure 2. Changes in flower diameter (A) and fresh weight (B) of cut flower in holding solution after simulated shipping for 4 days at 5°C by dry and wet harvesting solution treatment in standard chrysanthemum 'Baekma'. Vertical bars indicate standard deviation (n=3).

Table 2. Vase life of cut flower in holding solution after simulated shipping for 4 days at 5°C by dry and wet harvesting solution treatment in standard chrysanthemum 'Baekma'.

Treatment	Vase life (days)
Dry	18.6 b ^z
Tap water	20.7 a
Chrysal OVB	20.0 a
Hiflora	19.9 a
Floralife	20.3 a

^zMean separation within column by Duncan's multiple range test at 5% level.

'Siberia' and 'Medusa' extends the vase life and reduces bending of cut flowers. Floralife is also used as a pretreatment solution or preservative solution for roses, and it extended the vase life in 10 mL · L⁻¹ treatment as a wet harvesting solution in the shipping process during the export of cut roses, while also maintaining high fresh weight and showing effect on the quality (Lee, 2010; Lee, 2011). This study also showed that Chrysal OVB, Floralife, Hiflora used as cut flower life extender are we harvesting solutions effective on the quality and vase life of cut flowers than dry treatment, but there was no big difference in terms of effect from using tap water as the wet harvesting solution.

Quality and vase life of cut flower by NaOCl treatment as a wet harvesting solution

To determine the quality of cut flowers by NaOCl treatment as a wet harvesting solution for standard chrysanthemum 'Baekma', cut flowers were immediately put into 0, 12.5, 25, 50, 100, 200 mg · L⁻¹ solutions after harvesting. Table 3 shows the result of examining the changes in flower diameter and fresh weight after simulated shipping for 4 days at 5°C. The flower diameter was smallest in 200 mg · L⁻¹ NaOCl treatment (96.0%), and showed no significant difference in 0~100 mg · L⁻¹ NaOCl (97.7~99.9%). The fresh weight was maintained at the highest in 100 mg · L⁻¹ NaOCl (97.1%), and was low in 0, 12.5, 200 mg · L⁻¹ NaOCl (93.0~95.0%). Therefore, the quality of cut flowers after simulated shipping was favorable in 25~100 mg · L⁻¹ NaOCl treatment.

Standard chrysanthemum 'Baekma' was put in each concentration of the NaOCl solution immediately after harvesting. The cut flowers were put in preservative solutions after simulated shipping for 4 days at 5°C, and the quality and vase life

Table 3. Changes in flower diameter and fresh weight of cut flower after simulated shipping for 4 days at 5°C by NaOCl treatment as wet harvesting solution in standard chrysanthemum 'Baekma'.

NaOCl (mg · L ⁻¹)	% of initials	
	Flower diameter	Fresh weight
0	97.1 ab ^z	95.0 b
12.5	97.0 ab	94.6 b
25	99.9 a	95.4 ab
50	96.7 ab	96.2 ab
100	97.0 ab	97.1 a
200	96.0 b	93.0 c

^zMean separation within column by Duncan's multiple range test at 5% level.

of the cut flowers were examined every 2 days. The flower diameter was smallest in $200 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment, and it was 323.6% (6.5 cm) of the initial diameter on Day 20 in the preservative solution. On the other hand, the flower diameter was 392.4% (7.8 cm), which was biggest, in the preservative solution during $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment on Day 22 (Fig. 3A). The fresh weight increased in the preservative solutions to Days 8-10 and then decreased, and it was lower in 0 and $200 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment at 115.9% and 117.9%, respectively, than other treatments, and also showed statistical difference. On the other hand, the fresh weight in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment was highest at 128.2% in Day 10 (Fig. 3B). The vase life was longest in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment at 23.2 days, and it was short in 0 and $12.5 \text{ mg} \cdot \text{L}^{-1}$ NaOCl treatment at 21.7~21.9 days, and also showed statistical significance (Table 4).

NaOCl is a germicide that suppresses propagation of microorganisms, prevents closing of stem vessels, and promotes absorption of moisture. Using $100\text{--}200 \text{ mg} \cdot \text{L}^{-1}$ NaOCl as pretreatment solution for cut chrysanthemum 'Shinma' increased the quality and vase life of cut flowers (Yoo et al., 2016). Moreover, for cut chrysanthemum 'Baekma', using $50 \text{ mg} \cdot \text{L}^{-1}$ NaOCl as a preservative solution was effective for maintaining the freshness of cut flowers (Yoo and Roh, 2015b). For oriental lily 'Casa Blanca,' the vase life was extended by 3 days in $40 \text{ mg} \cdot \text{L}^{-1}$ NaOCl as the preservative solution compared to the control group, and the flower diameter and fresh weight were also high (Hwang et al., 2009). This study also showed that using $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl as a wet harvesting solution was effective in the quality and vase life of cut

Figure 3. Changes in flower diameter (A) and fresh weight (B) of cut flower in holding solution after simulated shipping for 4 days at 5°C by NaOCl treatment as wet harvesting solution in standard chrysanthemum 'Baekma'. Vertical bars indicate standard deviation ($n=3$).

Table 4. Vase life of cut flower in holding solution after simulated shipping for 4 days at 5°C by NaOCl treatment as wet harvesting solution in standard chrysanthemum 'Baekma'.

NaOCl ($\text{mg} \cdot \text{L}^{-1}$)	Vase life (days)
0	21.7 b ^z
12.5	21.9 b
25	22.3 ab
50	22.4 ab
100	23.2 a
200	22.8 ab

^zMean separation within column by Duncan's multiple range test at 5% level.

flowers than non-treatment, and this is proved to be more effective as a wet harvesting solution than Chrysal, Floralife, Hiflora used in Experiment 1.

Quality and vase life of cut flower by mixed use of NaOCl and sucrose treatment as a wet harvesting solution

Cut flowers were put into $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl mixed with 0, 0.02, 0.1, 0.5, 2.5% sucrose as a wet harvesting solution for standard chrysanthemum 'Baekma' immediately after harvesting. Table 5 shows the result of examining the changes in flower diameter and fresh weight after simulated shipping for 4 days at 5°C . The flower diameter was smallest in 0.02% sucrose treatment (97.1%), and was high in 0.1 and 0.5% sucrose treatment (100.0~100.1%) with statistical significance. The fresh weight remained high in 0.1~2.5% sucrose treatment (96.3~98.4%) with statistical significance, and was low in 0 and 0.02% sucrose treatment (95.4 and 95.9%). Therefore, the quality of cut flowers after simulated shipping was favorable in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl mixed with 0.1% sucrose.

Standard chrysanthemum 'Baekma' was put in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl mixed with each concentration of sucrose immediately after harvesting. The cut flowers were put in preservative solutions after simulated shipping for 4 days at 5°C , and the quality and vase life of the cut flowers were examined every 2 days. The flower diameter remained highest in 0.1% sucrose treatment, and was 488.1% (9.8 cm) on Day 18 in the preservative solution. On the other hand, the diameter was smaller in 0 and 2.5% sucrose treatment on Day 16 at 430.9% (8.6 cm) and 434.6% (8.7 cm) compared to other treatments, showing statistical significance (Fig. 4A). The fresh weight of cut flowers increased in 0.02, 0.1, 0.5% sucrose treatment until Day 14 and then decreased, and it was highest in 0.1% sucrose treatment, increasing up to 139.5%. On the other hand, the fresh weight in 0 and 2.5% sucrose treatment increased until Day 8 and then decreased, showing the lowest weight in 2.5% sucrose treatment (124.7%) (Fig. 4B). The vase life was 20.3~20.7 days regardless of sucrose concentration, showing no statistical difference (Table 5).

Sucrose added to cut flower life extenders induces complete flowering of cut flowers harvested in bud state like lilies, roses and chrysanthemums, and also promotes moisture absorption (Byun et al., 2004; Ichimura et al., 1999; Yoo and Roh, 2015b). This study showed that sucrose treatment resulted in bigger flower diameter than non-treatment, thereby inducing complete flowering. Sucrose generally is known to be effective in maintaining freshness of cut flowers at the concentration level of 2~3% (O'Donoghue et al., 2002; Zhang et al., 2012). However, treating more than 3% of sucrose as a preservative solution for cut chrysanthemum 'Baekma' will rather hinder moisture absorption and reduce fresh weight, turning the leaves yellow (Yoo and Roh, 2015b). Moreover, chrysanthemum 'Shinma' also showed wilting of leaves at an

Table 5. Changes in flower diameter and fresh weight of cut flower after simulated shipping for 4 days at 5°C by sucrose treatment mixed with $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl as wet harvesting solution in standard chrysanthemum 'Baekma'.

Sucrose (%)	% of initials	
	Flower diameter	Fresh weight
0	98.5 ab ^z	95.9 b
0.02	97.1 b	95.4 b
0.1	100.1 a	97.1 a
0.5	100.0 a	96.3 ab
2.5	98.7 ab	98.4 a

^zMean separation within column by Duncan's multiple range test at 5% level.

Figure 4. Changes in flower diameter (A) and fresh weight (B) of cut flower in holding solution after simulated shipping for 4 days at 5°C by sucrose treatment mixed with 100 mg·L⁻¹ NaOCl as wet harvesting solution in standard chrysanthemum 'Baekma'. Vertical bars indicate standard deviation (n=3).

Table 6. Vase life of cut flower in holding solution after simulated shipping for 4 days at 5°C by sucrose treatment mixed with 100 mg·L⁻¹ NaOCl as wet harvesting solution in standard chrysanthemum 'Baekma'.

Sucrose (%)	Vase life (days)
0	20.3 a ^z
0.02	20.5 a
0.1	20.7 a
0.5	20.4 a
2.5	20.3 a

^zMean separation within column by Duncan's multiple range test at 5% level.

early stage when the cut flowers were pretreated in the sucrose solution of at least 2.5% (Yoo et al., 2016). This study also showed that flower diameter and fresh weight decreased in NaOCl mixed with 2.5% sucrose as a wet harvesting solution compared to other treatments. This implies that unlike other cut flowers, cut chrysanthemum requires relatively lower concentration of sucrose to absorb moisture. Therefore, for cut chrysanthemum 'Baekma', the flower diameter and fresh weight increase when the cut flowers are treated immediately after harvesting in 100 mg·L⁻¹ NaOCl mixed with 0.1% sucrose, and thus the solution can replace other products that have been used.

Conclusion

This study was conducted to determine an effective wet harvesting solution to develop a wet distribution system for standard chrysanthemum 'Baekma'. Studies on wet solutions have been conducted for cut flowers such as roses and lilies, and roses were using wet solutions for shipping during the process of local distribution or export. Shipping cut flowers in the dry condition easily causes the flowers and leaves to dry and wilt due to lack of nutrients, and also deteriorates the quality of flowers. On the other hand, using a wet solution is effective for maintaining freshness and vase life of cut flowers by retaining moisture and providing nutrients (Lee and Kim, 2016; Lim et al., 2016).

In general, cut flower farms harvest cut flowers and leave them in the greenhouse or shed for hours to deal with them as

a batch job later. In particular, leaving cut flowers in high temperature during summer increases the breathing quantity of plants due to increased temperature, and deteriorates their quality as the leaves wilt due to dehydration. There is almost no research on wet harvesting solutions to be treated immediately after harvesting.

Therefore, this study compared the quality of cut flowers by treating them immediately after harvesting in dry condition and cut flower life extenders, and then in NaOCl and sucrose solutions to examine the effects on the quality and vase life of cut flowers. The flower diameter and fresh weight increased and the vase life extended when the cut flowers were put in tap water, Chrysal OVB, Floralife, Hiflora for wet treatment immediately after harvesting, compared to dry treatment. However, there was no big difference in quality or vase life between tap water and cut flower life extenders.

Based on the results of Experiment 1, this study intended to develop a more effective wet harvesting solution than current cut flower life extenders. Thus, the cut flowers were treated in NaOCl (Yoo et al., 2016) used as pretreatment solution by concentration, and the potential of this as a wet harvesting solution was reviewed. The flower diameter and fresh weight increased in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl, and the vase life was also extended by 1.5 days than the control group. However, the flower diameter and fresh weight were low in 0 or $200 \text{ mg} \cdot \text{L}^{-1}$ NaOCl solution with high concentration.

Sucrose used as a component of pretreatment solution or preservative solution induces complete flowering of flowers in bud state, promotes moisture absorption, and increases fresh weight (Huh et al., 2015; Reid and Kofranek, 1980). Therefore, this study treated cut flowers in each concentration of sucrose mixed in NaOCl $100 \text{ mg} \cdot \text{L}^{-1}$, and the flower diameter was highest at 9.8 cm in the solution mixed with sucrose 0.1%, and the fresh weight was also highest in the preservative solution. On the other hand, both the fresh weight and flower diameter were lowest in the wet solution mixed with 2.5% sucrose. The vase life was not different between treatments mixed with sucrose. Therefore, it was found that it would be most effective for the quality and vase life of cut flowers to treat standard chrysanthemum 'Baekma' in $100 \text{ mg} \cdot \text{L}^{-1}$ NaOCl mixed with 0.1% sucrose as a wet harvesting solution immediately after harvesting.

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