Handling and Opening Bud-Cut Chrysanthemum Flowers With 8-Hydroxyquinoline Citrate and Sucrose

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SUMMARY

Chrysanthemums harvested as buds (50 to 60 millimeters diameter) and held in 8-hydroxyquinoline citrate (8–HQC) plus sucrose were successfully opened off the plant. Optimum concentrations of 8–HQC and sucrose were 200 parts per million (p.p.m.) and 2-percent, respectively. Buds harvested as small as 30 millimeters (mm.) in diameter opened in 8–HQC plus sucrose, but the 30 mm. buds developed into smaller flowers than larger buds.

Light intensity and duration had little influence on flower opening. The influence of darkness on flower opening was not evaluated.

Flowerbuds of most cultivars were successfully opened in 8–HQC plus sucrose in a laboratory at 74° F. Flowers of all cultivars had improved form when buds were opened and held in 8–HQC plus sucrose rather than in water.

Open flowers or buds held in 8–HQC plus sucrose maintained their fresh weight longer and had a longer vase-life than flowers and buds held in water. Foliage on stems held in 8–HQC plus sucrose eventually became chlorotic.

Open flowers and buds were successfully dry stored for 3 weeks at 31° F. Stored buds opened as well as freshly harvested buds in 8–HQC plus sucrose. Flowers from stored buds lasted as long as flowers from freshly harvested buds, but flowers from buds had a vase life slightly less than freshly harvested fully open flowers.

Buds harvested and held in 8–HQC plus sucrose opened as well as flowers held intact on the plant. Flower form and quality was similar for both groups.

INTRODUCTION

Chrysanthemum flowers are normally harvested commercially after they have fully opened on the plant. If flowers could be harvested in the bud stage and allowed to develop in chemical solution rather than on the plant, flower growers would have much greater flexibility in their cultural and marketing programs. Flower growers harvesting chrysanthemum flowers as buds might also use their facilities more efficiently by producing more crops per year. Flowerbuds might be less susceptible to disease infection or injury during harvest. Storing flowers as buds could be of great commercial value. A flower grower might store flowerbuds and open them when market demand is high, as before a holiday. Further, greater quantity of buds than of open flowers could be stored in a

given volume. Besemer *(1)*[1] [2] shipped chrysanthemums in the bud stage from California to New York in exploratory work and successfully opened these flowers in commercial preservative solutions. He indicated that the maximum benefits to be derived from shipping standard chrysanthemum flowers in the bud stage would be savings in transportation costs, less damage to flowers, and the possibility of the wholesaler's stockpiling flowers.

Waters *(15)* showed that 'Iceberg' pompom chrysanthemum flowers harvested at the tight-bud stage increased in diameter and fresh weight when held in commercial floral preservatives. He also reported that commercial floral preservatives had a deleterious effect on chrysanthemum foliage.

Woltz *(16, 17)* and Woltz and Waters *(18)* demonstrated that the photosynthetic capacity of chrysanthemum cut flowers may be important in extending vase life. Cut flowers exposed to light during refrigerated storage retained the photosynthetic capacity and sugar content of leaves at higher levels and for longer durations than cut flowers stored in darkness and at elevated temperatures. Light and refrigeration benefited blossoms, but not to the same extent that these factors benefited leaves.

The technique of opening flowers harvested in the bud stage was successfully demonstrated on carnations by Kohl and Smith *(6)*. They showed that flowers cut as buds developed as well in commercial floral preservatives as flowers held intact on the plant. Flowers that developed from buds and flowers that were harvested open had similar lasting quality. Holley and Cheng *(4)* demonstrated similar results with carnations and showed that a mixture of quinoline salts and sucrose was superior to several other flower preservatives in aiding flower opening and extending vase life. Hardenburg and others *(5)* have shown that bud-cut carnations could be shipped from California and Colorado to Maryland and opened successfully in floral preservative solutions. Other workers, using quinoline salts and sucrose solutions, demonstrated that carnations *(7)*, roses *(11, 14)*, snapdragons *(8)*, stocks *(9)*, and gladiolus *(10)* grew larger and had longer vase life than flowers held in water.

The study reported here was undertaken to determine the feasibility of handling and opening standard chrysanthemum flowers, cut in the bud stage, with solutions of 8-hydroxyquinoline citrate (8–HQC) and sucrose.

GENERAL METHODS AND MATERIALS

Chrysanthemum flowers used in these experiments were obtained from commercial flower fields in the vicinity of Bradenton, Fla., or were grown in experimental plots at the Gulf Coast Experiment Station. Flowers grown as single stems were harvested in the morning, placed in cardboard shipping containers, and brought to the laboratory at the Gulf Coast Experiment Station. In the laboratory, stems were trimmed to 18-inch lengths and the foliage was removed from the lower third of each stem. Two or three flowers were placed in single quart jars containing water (the control) or various chemical opening solutions. A minimum of six flowers was used for each treatment. Distilled water was used for the control and for preparing all chemical solutions. Jars were scrubbed with a detergent solution and rinsed in distilled water before each experiment.

Bud and flower diameters and fresh weights of individual stems with flowers were determined initially and at periodic intervals during the tests. Data are expressed either as percentage increase or as millimeter and gram increase from original values (to eliminate variation in sample dimensions) for those flowers that could not be cut at the exact size and weight as were specified for the tests. Liquids in jars were renewed every 3 to 4 days with freshly prepared chemical solutions or water. In a few experiments, the volume of liquid lost was determined to obtain patterns of solution absorption. Flowers were held in water or solution in the laboratory, which was maintained at 74 ± 2° F., and a continuous light intensity of 200

[1] Italic numbers in parentheses refer to Literature Cited, p. 13.

[2] Besemer, S. T. Also, personal communications. 1967.

foot-candles was supplied by fluorescent tubes. Relative humidity was not controlled, but ranged from 55 to 75 percent. The laboratory served as opening room, with environment and flower-handling procedure as described above constituting standard conditions in the opening room for purposes of the tests. All flowers were harvested and held in a standard opening-room environment except when otherwise noted in descriptions of specific experiments. Cut flowers, except those used in storage experiments, were placed in solutions ¼ of an hour to 1 hour after harvest.

Vase life was measured from the day flowers or buds were harvested and placed in the opening room. Days required for flower development from buds to open flowers were subtracted from total days of vase life. Vase life was considered terminated when flower petals lost turgidity or decorative value, or both. Foliage condition was not used as a criterion for vase life. (Exceptions to this rule are noted in specific experiments.)

All data were treated by analysis of variance and the means were compared by Duncan's Multiple Range Test. In most factorial experiments, only main effects are reported.

SPECIFIC TESTS WITH EXPERIMENTAL OPENING MEDIA

Determining Optimum Levels of Opening-Solution Components

'Indianapolis White' chrysanthemum flowerbuds were harvested when 45 mm. in diameter and were placed in 0-, 2-, or 4-percent sucrose solutions. Buds were placed in the opening room and their diameters were measured at 6 and 8 days.

'Albatross' chrysanthemum flowerbuds were used in a second experiment. Buds were harvested when 45 to 55 mm. in diameter and were held in solutions of 0-, 200-, or 400-p.p.m. 8-hydroxyquinoline citrate (8–HQC) factorially arranged with 0- and 2-percent sucrose. Buds were placed in the opening room and their diameters and fresh weights were measured at the 4th and 7th day.

In a third experiment, 'Mrs. Roy' chrysanthemum flowerbuds were harvested when 55 mm. in diameter. These buds were held in solutions containing 2- or 4-percent sucrose factorially combined with 200-, 400-, or 600-p.p.m. 8–HQC. Flowers were placed in the opening room and their diameters and fresh weights were determined at 4 and 7 days.

'Indianapolis White' flowers held in sucrose were larger than those held in water, but no differences in diameters were found between flowers treated with 2- and with 4-percent sucrose (table 1). Neither the buds opened and held in water nor those held in sucrose increased in size after 6 days. Flowers held in water were not as well developed as those held in sucrose. Whereas flowers held in sucrose had the globular shape typical of

TABLE 1.—*Diameter of cut 'Indianapolis White' chrysanthemum flowerbuds held in sucrose solutions*[1]

Sucrose levels (percent)	Diameter measurements after—	
	6 days[2]	8 days[2]
	Mm.	*Mm.*
0	76a	80a
2	97 b	91 b
4	96 b	96 b

[1] Initial flowerbud diameters were 45 mm.
[2] Means within each column are significantly different at the 1-percent level when followed by different letters.

flowers opened on the plant, flowers held in water were flattened and quilled. After 14 days at 74° F., the foliage of stems held in 4-percent sucrose became chlorotic, but the foliage of those held in water did not. Foliage on stems held in 2-percent sucrose became only slightly chlorotic. Flowers held in water wilted first, and were successively followed by the flowers held in 4- and 2-percent sucrose.

All 'Albatross' chrysanthemums held in sucrose and 8–HQC combinations increased in diameter with time (table 2). Both sucrose and 8–HQC, when used singly, aided flower opening; however, the largest flowers were those held in 200-p.p.m. 8–HQC plus 2-percent sucrose. Flowers held in 8–HQC plus sucrose or in sucrose alone were globular, but those held in water were considerably smaller and were flat in appearance (fig. 1).

Flowers held in water or various combinations of 8–HQC and sucrose for 4 days increased in

TABLE 2.—*Percentage increases in diameters of cut 'Albatross' chrysanthemum flowerbuds held in 8–HQC and sucrose solutions*

Component levels in solution		Diameter increase [1] after—	
8–HQC level	Sucrose level	4 days [2]	7 days [3]
P.p.m.	*Percent*	*Percent*	*Percent*
0	0	93.7 d	110.4
0	2	123.9 bc	143.6
200	0	99.3 cd	136.8
200	2	161.6a	180.0
400	0	130.8 b	151.2
400	2	131.4 b	163.9

[1] Initial flowerbud diameters were 45 to 55 mm.
[2] Means within the column followed by different letters are significantly different at the 5-percent level.
[3] Sucrose and 8–HQC main effects are significantly different at the 1-percent level. Sucrose and 8–HQC interaction is not significantly different.

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FIGURE 1.—'Albatross' crysanthemum flowers 7 days after cut buds were placed *(left)* in water and *(right)* in chemical solution. Flowers opened in the control (water) are smaller and flatter than those opened in the 8–hydroxyquinoline citrate and sucrose solution.

fresh weight, but the differences between the treatments were not significant (table 3). Flowers held in sucrose for 7 days increased in fresh weight more than flowers held in water.

No differences were apparent in flower diameter or fresh weight of 'Mrs. Roy' chrysanthemums held in the various concentrations of 8–HQC and sucrose (data not presented). At 7 days, flowers afforded the six treatments had diameters that averaged 123 to 127 mm. After 7 days, stems weighed 56 to 60 grams, a 65- to 69-percent increase over initial weights.

TABLE 3.—*Percentage increase in fresh weights of cut 'Albatross' chrysanthemum flowerbuds held in 8–HQC and sucrose solutions*

Main effects of 8–HQC and sucrose levels in solutions	Fresh weight increase [1] after—	
	4 days [2]	7 days [2]
8–HQC:	*Percent*	*Percent*
0	24.0a	33.4a
200 p.p.m.	27.4a	38.0a
400 p.p.m.	26.7a	37.6a
Sucrose:		
0	23.7a	31.4a
2 percent	28.3a	41.3 b

[1] Initial stem fresh weights were 49 to 64 grams. Initial flowerbud diameters were 45 to 55 mm.
[2] Means within a treatment group followed by different letters are significantly different at the 5-percent level.

Effects of Bud Sizes on Flower Diameter

'Albatross' chrysanthemums were harvested in three stages of flowerbud development: when they were 30, 45, or 60 mm. in diameter (fig. 2). Buds from each group were placed in the opening room in water or in opening solution (200-p.p.m. 8–HQC and 2-percent sucrose). Flower diameters and fresh weights were recorded after 4, 7, and 10 days. Vase life was also recorded.

The larger the flowerbuds were at harvest, the larger the flower diameters measured at 7 days (table 4). Buds held in water were smaller than those held in opening solution. Buds held in water did not develop after 4 days, but those held in the opening solution continued to increase in size. However, buds held in the opening solution increased in diameter more the first 4 days than the last 3 days. Buds from each group reached their maximum diameters in 7 days. Although the 30-mm. buds developed into smaller flowers than the

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FIGURE 2.—'Albatross' chrysanthemum flowerbuds with *(left to right)* 30–, 45–, and 60–mm. diameters were harvested for opening-solution test.

TABLE 4.—*Diameter of 'Albatross' chrysanthemum flowerbuds cut at 3 stages of development and held in water or in opening solution*

Initial bud diameter and opening medium	Diameter after [1]—		
	4 days	7 days	10 days
	Mm.	*Mm.*	*Mm.*
30 mm.:			
Water	64 b	68 b	73 b
Opening solution [2]	75 b	99a	106a
45 mm.:			
Water	93 c	94 c	97 bc
Opening solution [2]	102 b	116a	120a
60 mm.:			
Water	104 c	103 c	108
Opening solution [2]	120 b	128a	131a

[1] Means within the 30–mm. group are significantly different at the 1-percent level when followed by different letters. Means within the 45-mm. group and the 60-mm. group, respectively, are significantly different at the 5-percent level when followed by different letters.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

60 mm. buds, the 30-mm. buds held in opening solution produced flowers comparable in form to flowers produced from 45- and 60-mm. buds.

All buds increased in fresh weight during the first 4 days of development (table 5). Flowerbuds held in opening solution continued to increase in fresh weight for 7 days, but those held in water attained their maximum weight in 4 days.

All flowers held in the opening solution had the same vase life: 13 to 14 days.

TABLE 5.—*Fresh weight changes in 'Albatross' chrysanthemums cut at 3 stages of flowerbud development and held in water or in opening solution*

Treatments		Fresh weight changes after [1]—		
Initial Diameter	Opening Solution	0 days	4 days	7 days
		Gram	*Gram*	*Gram*
30 mm.	Water	22.6 c	27.3 bc	27.0 bc
30 mm.	Opening solution [2]	21.5 c	32.9 b	40.4a
45 mm.	Water	37.6 c	51.0 b	51.2 b
45 mm.	Opening solution [2]	38.9 c	57.9 b	66.6a
60 mm.	Water	44.6 c	59.9ab	58.8 b
60 mm.	Opening solution [2]	37.5 c	59.6ab	67.6a

[1] Means within an initial diameter group are significantly different at the 1-percent level when followed by different letters.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

Effects of Light on Bud Opening

'Albatross' chrysanthemum flowerbuds were harvested when 55 to 60 mm. in diameter and were placed in water or opening solution (200-p.p.m. 8–HQC and 2-percent sucrose). These were placed in the opening room (74° F.) and factorially arranged at light intensities of 75, 150 and 450 foot-candles (ft.-c.), supplied continuously by fluorescent tubes. Flower diameters and water and solution absorption were measured at 4, 7, and 10 days. Liquids in jars were renewed with freshly prepared solutions or water every 3 or 4 day, at which time volume loss was determined. Flower fresh weights were determined at 4, 7, 10, and 25 days.

In a second experiment, two lighting arrangements were provided for cut 'Albatross' flowerbuds. Buds were harvested when 55 to 60 mm. in diameter, trimmed, and placed in the opening room with either 150 or 450 ft.-c. of light for 6, 12, or 24 hours daily. Flowers were placed in water or in opening solution. All experimental variables were combined in a 2 by 3 by 2 factorial arrangement. Flower diameters, fresh weights, and liquid absorptions were measured at 4, 7, and 10 days.

After 4 days, flowers held at 75 ft.-c. had not opened as much as flowers held at 150 or 450 ft.-c. (table 6), but after 7 and 10 days, no differences were found in flower diameters. Flowers held in water or opening solution reached their maximum size at the 7th day, but those held in water were smaller. Various light intensities during opening did not predispose the flowers to longer life. Use of an opening solution greatly increased flower life.

Light had no influence on flower and stem fresh weight, but use of an opening solution increased fresh weight (table 7). Flowers held in water reached their maximum fresh weight in 7 days and gradually declined in weight thereafter, but flowers held in opening solution continued to increase in weight up to 10 days. Fresh weights of flowers held in opening solution were maintained longer than weights of flowers held in water.

TABLE 6.—*Main effects of light intensity on the increase in diameter and vase life of cut 'Albatross' chrysanthemum flowerbuds held in water or in opening solution*

Light intensity and opening medium	Diameter increase[1] after[2]—4 days	7 days	10 days	Vase life[2]
	Mm.	*Mm.*	*Mm.*	*Days*
Light intensity:				
75 ft.–c	47a	59a	62a	15.6a
150 ft.–c	58 b	66a	68a	16.8a
450 ft.–c	62 b	67a	62a	16.6a
Opening medium:				
Water	51a	56a	54a	11.8a
Opening solution[3]	60 b	72 b	75 b	20.6 b

[1] Initial flowerbud diameters were 50 to 60 mm.
[2] Means within the "light intensity" group and the "opening medium" group, respectively, are significantly different at the 1-percent level when followed by different letters.
[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

TABLE 7.—*Main effects of light intensity and opening solution on increase in fresh weights of cut 'Albatross' chrysanthemums held in water or opening solution*

Light intensity and opening medium	Fresh weight increase after[1]—4 days	7 days	10 days	25 days
	Grams	*Grams*	*Grams*	*Grams*
Light intensity:				
75 ft.–c	12.0a	18.5a	21.3a	13.9a
150 ft.–c	14.1a	21.6a	24.3a	12.9a
450 ft.–c	13.8a	20.2a	22.5a	15.4a
Opening medium:				
Water	11.6a	14.5a	13.5a	3.3a
Opening solution[2]	15.0 b	25.7 b	31.9 b	24.8 b

[1] Means within the "light intensity" group and the "opening medium" group, respectively, are significantly different at the 1-percent level when followed by different letters.
[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

Flowers held at 75 ft.-c. absorbed less solution or water than those held at 150 or 450 ft.-c. (table 8). Flowers held in opening solution absorbed more liquid than those held in water. All flowers absorbed less water or solution as time passed, but the rate of change was less for flowers held in opening solution than for those held in water.

Flowers held in opening solution were larger than those held in water (table 9). Flowers held in water or opening solution reached their maximum diameters in 7 days. Light intensity or duration had no appreciable influence on flower diameter.

TABLE 8.—*Main effects of light intensity on liquid absorption by cut 'Albatross' chrysanthemums held in water or in opening solution*

Light intensity and opening medium	Liquid absorption during[1]— 4 days	7 days	10 days
	Ml.	*Ml.*	*Ml.*
Light intensity:			
75 ft.–c.	206a	158a	153a
150 ft.–c.	280 b	219 b	190 b
450 ft.–c.	328 b	246 b	213 b
Opening medium:			
Water	263a	183a	144a
Opening solution[2]	280 b	233 b	226 b

[1] Means within the "light intensity" group and the "opening medium" group, respectively, are significantly different at the 1-percent level when followed by different letters.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

TABLE 9.—*Increase in diameter of cut 'Albatross' chrysanthemum flowers held in opening solution or in water at various light intensities and durations*

Opening medium and light intensity and duration	Diameter increase[1] after[2]— 4 days	7 days	10 days
	Mm.	*Mm.*	*Mm.*
Opening medium:			
Water	32.1a	38.2a	40.2a
Opening solution[3]	52.8 b	63.4 b	65.5 b
Light intensity:			
150 ft.–c.	42.7a	51.3a	53.1a
450 ft.–c.	42.2a	50.2a	52.5a
Light duration:			
6 hr.	42.3a	52.6a	55.2a
12 hr.	41.5a	50.8a	52.0a
24 hr.	43.5a	49.0a	51.3a

[1] Initial flowerbud diameters were 55 to 60 mm.

[2] Means within the "opening medium" group, the "light intensity" group, and the "light duration" group, respectively, are significantly different at the 1-percent level when followed by different letters.

[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

Flowers held in opening solution increased in fresh weight more than those held in water (table 10). Flowers held in water reached their maximum fresh weight in 4 days whereas flowers held in opening solution continued to increase in weight for 7 days. Light intensity did not influence fresh weight. Flowers held in light for 24 hours weighed less than flowers held in light for 6 hours after 7 and 10 days.

No differences were found in liquid absorbed by flowers held in water or opening solution for 4 or 7 days (table 11), but flowers held for 10 days in opening solution absorbed more liquid. Flowers held for 7 days at 450 ft.-c. absorbed more liquid than those held at 150 ft.-c. At 4 and 10 days, light intensity did not influence liquid absorption.

TABLE 10.—*Fresh weight changes of cut 'Albatross' chrysanthemums held in opening solution or in water at various light intensities for different periods*

Opening medium and light intensity and duration	Weight change[1] after[2]— 4 days	7 days	10 days
	Grams	*Grams*	*Grams*
Opening medium:			
Water	10.1a	8.8a	8.0a
Opening solution[3]	15.4 b	19.2 b	20.9 b
Light intensity:			
150 ft.–c.	12.6a	13.5a	15.4a
450 ft.–c.	12.9a	14.5a	13.6a
Light duration:			
6 hr.	13.3a	16.4a	17.3a
12 hr.	12.3a	14.1ab	14.6ab
24 hr.	12.7a	11.5 b	11.5 b

[1] Initial stem fresh weights were 40 to 50 grams.

[2] Means within the "opening medium" group, the "light intensity" group and the "light duration" group, respectively, are significantly different at the 1-percent level when followed by different letters.

[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

TABLE 11.—*Influence of light intensity and duration and opening medium on liquid absorption by cut 'Albatross' chrysanthemums*

Opening medium and light intensity and duration	Solution uptake during[1]— 4 days	7 days	10 days
	Ml.	*Ml.*	*Ml.*
Opening medium:			
Water	274a	172a	130a
Opening solution[2]	311a	198a	150 b
Light intensity:			
150 ft.–c.	284a	169a	133a
450 ft.–c.	301a	200 b	147a
Light duration:			
6 hr.	260 b	177a	137a
12 hr.	297ab	181a	136a
24 hr.	321a	197a	147a

[1] Means within the "opening medium" group are significantly different at the 1-percent level when followed by different letters. Means within the "light intensity" group and the "light duration" group, respectively, are significantly different at the 5-percent level when followed by different letters.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

At 4 days, flowers held in light for 24 hours absorbed more liquid than those held in light for only 6 hours. Light duration did not influence liquid absorption at 7 and 10 days.

Cultivar Response to Opening-Media Treatments

Flowerbuds of several cultivars of chrysanthemum were harvested when buds were 55 to 60 mm. in diameter and were placed in water or opening solution (200 p.p.m. 8–HQC and 2-percent sucrose). Cultivars used are listed in tables 12 and 13. All cultivars were grown as single stems except 'Indianapolis White,' which was grown as a branched plant. Handling and measuring procedures were similar to those described for earlier experiments.

Flowers of most cultivars held in opening solution were larger than flowers of those held in water (table 12). The opening solution had little influence on the diameters of 'Explorer' flowers, but these flowers were more globular and had better form than 'Explorer' flowers held in water. 'Pink Champagne' and 'Mrs. Roy' flowers held in opening solution for 7 days retained their diameters, but diameters of flowers held in water decreased, indicating premature senescence. 'Yellow Albatross' and 'Indianapolis White' flowers held in water or opening solution for 7 days retained the same diameters they had at 4 days. Diameters of 'Yellow Knight' flowers were not measured, but flowers held in opening solution were larger and lasted longer than those held in water.

Flowers of most cultivars lasted longer when held in opening solution than in water. Vase-life records were not collected on 'Indianapolis White' and 'Explorer.' 'Indianapolis White' stems collapsed after 10 days in solutions and 'Explorer'

TABLE 12.—*Diameters and vase life of flowers of 6 chrysanthemum cultivars harvested as buds and held in water or in opening solution*

Cultivar and opening media	Diameter[1] after—		Vase[1] life
	4 days	7 days	
	Mm.	*Mm.*	*Days*
'Pink Champagne':			
Water	113	100 c	5.3a
Opening solution[2]	128a	131a	6.3a
'Albatross':			
Water	107a	105a	10.0a
Opening solution[2]	121 b	125 b	12.0 b
'Yellow Albatross':			
Water	110a	108a	10.3a
Opening solution[2]	118 b	125 b	13.0 b
'Mrs. Roy':			
Water	111 b	94 c	2.0a
Opening solution[2]	121a	116ab	11.0 b
'Indianapolis White':			
Water	107 b	98 c	([3])
Opening solution[2]	120a	110 b	([3])
'Explorer':			
Water	81a	85a	([3])
Opening solution[2]	86a	94a	13.8

[1] Initial flowerbud diameters were 55 to 60 mm. Any 2 means for a given cultivar are significantly different at the 1-percent level when followed by different letters. Statistical comparisons cannot be made between 2 varieties.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

[3] Indicates no records collected. See p. 8 for explanation.

TABLE 13.—*Fresh weight changes of 7 chrysanthemum cultivars harvested as buds and held in water or in opening solution*

Cultivar and opening media	Fresh weight changes[1] after—		
	0 days	4 days	7 days
	Grams	*Grams*	*Grams*
'Pink Champagne':			
Water	45.1 b	53.2 b	48.3 b
Opening solution[2]	44.6 b	64.4a	69.8a
'Albatross':			
Water	44.9 d	59.9 c	59.3 c
Opening solution[2]	43.3 d	66.0 b	73.6a
'Yellow Albatross':			
Water	49.3 c	65.8 b	66.5 b
Opening solution[2]	49.7 c	71.5 b	78.5a
'Mrs. Roy':			
Water	29.1 d	39.2 c	32.8 d
Opening solution[2]	30.0 d	47.1 b	53.5a
'Indianapolis White':			
Water	33.6 de	37.6 c	36.0 cd
Opening solution[2]	32.5 e	46.0 b	52.2a
'Explorer':			
Water	35.9 b	43.8a	41.1a
Opening solution[2]	35.5 b	42.4a	45.2a
'Yellow Knight':			
Water	26.5 cd	34.3 b	31.9 bc
Opening solution[2]	23.7 d	35.3 b	42.1a

[1] Initial flowerbud diameters were 55 to 60 mm. Any 2 means for a given cultivar are significantly different at the 5-percent level when followed by different letters. Statistical comparisons cannot be made betwen 2 varieties.

[2] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

flowers held in water did not open sufficiently to justify record taking.

Flowers of all cultivars increased in fresh weight after 4 days, but flowers from most cultivars held in opening solution were heavier than those held in water (table 13). The opening solution did not influence the fresh weight of flowers of 'Explorer.' All flowers except 'Pink Champagne' and 'Explorer' that were held in opening solution increased in fresh weight from the 4th to the 7th day. Flowers from all cultivars held in water either remained unchanged or decreased in fresh weight during the same period.

Preservative Effects of Opening Media on Buds and Open Flowers

'Albatross' chrysanthemum flowers were harvested as buds (50 to 55 mm. in diameter), trimmed and placed either in water or opening solution (200 p.p.m. 8–HQC plus 2-percent sucrose) at standard conditions. To study the preservative effects of various opening media, the researchers divided the buds into two lots 7 days after they were placed in water or opening solution. One-half of the buds originally held in water were transferred to opening solution and the remaining half were placed in fresh water. Similarly, one-half of the buds originally held in opening solution were transferred to water and the remaining half were placed in fresh opening solution. At the same time buds were harvested, a group of 'Albatross' chrysanthemums were harvested open (110 to 115 mm. in diameter), trimmed and placed in water or opening solution. Treatments are summarized in table 14. Both buds and open flowers were grown and handled with similar cultural conditions except open flowers were physiologically 1 week older than buds. Flower diameter and percentage changes in fresh weight from initial fresh weight were recorded at weekly intervals. After 3 weeks, flowers were weighed so that an objective evaluation of vase life could be obtained.

Flowers harvested in the bud stage and held in water were not as large after 7 days as those held in opening solution (table 14). Flowers harvested as buds and held in opening solution were as large as flowers that were opened on the plant. Flowers harvested open continued to develop both in water and in opening solution. However, buds that were developed in opening solution and transferred to water after 7 days did not maintain their diameters as well as flowers held continuously in opening solution. Flowerbuds transferred to opening solution after 7 days in water showed no further increase in diameter. At 14 days, flowers harvested open and held continuously in opening solution were larger than those held in water.

Both open flowers and buds held in the opening solution for 7 days gained more weight than open flowers and buds held in water (table 15). Flowerbuds developed in opening solution for 7 days and then transferred to water for 14 days weighed less than those held continuously in opening solution. Use of the opening solution had no influence on fresh weight of flowerbuds that had previously been held in water for 7 days. Flowers harvested

TABLE 14.—*Diameters of 'Albatross' chrysanthemum flowers[1] held in water, in opening solution, or alternately in both media*

Developmental stage at harvest	Media used during—		Diameter after [2]—	
	0 to 7th day	8th to 14th day	7 days	14 days
			Mm.	*Mm.*
Bud	Water	Water	103 b	94 d
Bud	Water	Opening solution [3]	98 b	97 d
Bud	Opening solution [3]	Water	128a	108 c
Bud	Opening solution [3]	Opening solution [3]	125a	115 b
Open flower	Water	Water	123a	108 c
Open flower	Opening solution [3]	Opening solution [3]	132a	124a

[1] Flowers were harvested either as buds (initial diameters 50 to 55 mm.) or as open flowers (initial diameters 105 to 110 mm.)

[2] Means within a column are significantly different at the 1-percent level when followed by different letters.

[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

TABLE 15.—*Percentage changes in fresh weights of 'Albatross' chrysanthemum flowers held in water, in opening solution, or in both media*

Developmental stage at harvest	Media used during—		Changes in weight after [2]—		
	0 to 7th day	8th to 14th day	7 days	14 days	21 days
			Percent	*Percent*	*Percent*
Bud	Water	Water	25.1 c	16.2 b	4.3 bc
Bud	Water	Opening solution [3]	27.4 c	16.0 b	6.1 bc
Bud	Opening solution [3]	Water	50.1a	32.5a	−4.2 c
Bud	Opening solution [3]	Opening solution [3]	47.7a	47.9a	22.8ab
Open flower	Water	Water	20.3 c	10.7 b	−3.9 c
Open flower	Opening solution [3]	Opening solution [3]	37.5 b	44.5a	32.0 b

[1] Flowers were harvested either as buds (initial diameter 50 to 55 mm.) or as open flowers (initial diameters 105 to 110 mm.).
[2] Means within a column are significantly different at the 5-percent level when followed by different letters.
[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

open or in the bud stage and held in opening solution maintained their fresh weight longer than those held in water. Vase life paralled the changes in fresh weight; flowers held in opening solution had the greatest longevity.

Effects of Storage on Flowerbud Opening

'Albatross' chrysanthemum flowers were harvested when 50 to 60 mm. (buds) and 105 to 110 mm. (open) in diameter. Stems were cut to 30-inch lengths and the foliage was removed from the lower third of the stems. Flowers were handled and prepared for storage in a manner similar to that outlined by Mastalerz *(12)*, except for packing procedure. Commercial cardboard shipping cartons (20 by 11 by 54 inches) were lined with 2-mil polyethylene sheeting. Stems were packed in the cartons horizontally, and in each carton, a rolled newspaper was placed under the stems, immediately below the flowers or buds, to aid in raising them. The polyethylene sheeting was then folded over the flowers, and a lid was placed on the carton. Flowers were stored for 0, 1, 2, or 3 weeks at 30° to 33° F. After storage, the flowers were trimmed to standard length and placed in water or opening solution (200 p.p.m. 8–HQC plus 2-percent sucrose). All three experimental variables (flower size, storage time, and opening media) were arranged in a factorial experiment. After storage, and during opening, the flowers were examined as in previous experiments.

The diameters of flowers harvested in the bud stage and opened at 74° after storage increased for 7 days (table 16). Both buds and open flowers held in opening solution continued to increase in diameter for 7 days, but those held in water did not increase in diameter after 3 days. Storage of up to 3 weeks had no influence on subsequent flower diameters.

TABLE 16.—*Diameters of 'Albatross' chrysanthemum flowers harvested at 2 stages of development and held in water or opening solution after storage*

Developmental stage,[1] opening medium, and storage periods	Diameter after—	
	3 days [2]	7 days [2]
	Mm.	*Mm.*
Developmental stage at harvest:		
Bud	111 b	115a
Open flower	119a	115a
Opening medium:		
Water	110 b	105 b
Opening solution [3]	119a	126a
Storage periods at 30° to 33° F:		
None	115a	111a
1 week	113a	117a
2 weeks	113a	116a
3 weeks	119a	117a

[1] Initial diameter of buds and open flowers were 50 to 60 and 105 to 110 mm., respectively.
[2] Means within the "developmental stage" group, means within the "opening solution" group, and means within the "storage periods" group are significantly different at the 1-percent level, respectively, when followd by different letters.
[3] Opening soultion: 200 p.p.m. 8–HQC + 2-percent sucrose.

Flowers harvested open or as buds and held in water or opening solution gained the same amount of fresh weight after 3 days (table 17). After 7 days, flowers harvested in the bud stage continued to increase in fresh weight but flowers harvested open did not. Flowers held in opening solution increased in fresh weight for 7 days whereas those held in water did not increase in weight after 3 days. Time of storage did not significantly alter increases in fresh weight.

TABLE 17.—*Fresh weight changes and vase life of 'Albatross' chrysanthemum flowers harvested at 2 stages of development and held in water or in opening solution after storage*

Developmental stage,[1] opening medium, and storage periods	Weight increase after— 3 days [2]	7 days [2]	Vase life [2]
	Grams	*Grams*	*Days*
Developmental stage at harvest:			
Bud	14.1a	17.4a	9.0a
Open flower	14.1a	14.8 b	13.7 b
Opening medium:			
Water	11.4a	7.7a	10.0a
Opening solution [3]	16.8 b	24.5 b	12.5 b
Storage periods at 30° to 33° F:			
0	13.6a	14.8a	11.3a
1 week	13.7a	15.8a	10.8a
2 weeks	15.2a	17.7a	11.4a
3 weeks	14.0a	16.1a	11.0a

[1] Initial stem weights were 40 to 50 grams. Initial diameter of buds and open flowers were 50 to 60 and 105 to 110 mm., respectively.

[2] Means within the "developmental stage" group, means within the "opening medium" group, and means within the "storage period" group are significantly different at the 1-percent level, respectively, when followed by different letters.

[3] Opening solution: 200 p.p.m. 8–HQC + 2-percent sucrose.

Flowers held in opening solution after storage lasted longer than flowers held in water (table 17). Flowers harvested open lasted slightly longer than flowers harvested in the bud stage. Storage had no influence on vase life.

Development of Flowers From Treated Cut Buds and From Uncut Buds

'Mrs. Roy' chrysanthemums were grown as single stems in a greenhouse under approved commercial cultural practices at 60 to 65° F. night temperature and 70 to 75° F. day temperatures. The duration of photoperiod treatments was adjusted so that the final height of the plants was approximately 24 inches. Flowerbuds were selected on December 16, 1968, when the buds were 50 to 55 mm. in diameter. Some were harvested and placed in the experimental opening solution (200 p.p.m. 8–HQC plus 2-percent sucrose) or in water, and others were tagged and left intact on the plant. Flower diameter was measured at 2, 4, and 7 days. Flowers held in opening solution or water were harvested with 15-inch stems and were placed in the opening room at standard conditions. Intact flowers were maintained in the greenhouse at the growing temperatures, except during the first two nights after selection, when the temperature dropped to 50° F. During the rest of the experiment, the greenhouse temperature was adequately maintained at 60°.

During the first 2 days, flowerbuds left on the plant did not enlarge as much as buds cut and held in the opening solution (table 18). At 4 and 7 days, buds cut and held in opening solution developed into flowers as large as those held on the plant, with both groups having similar form. Floret color was more intense for flowers that developed on the plant than for those developed in the opening solution. Flowerbuds cut and held in water did not open as well as those held in opening solution or left on the plant. Buds held in water wilted in less than 7 days.

TABLE 18.—*Diameters of 'Mrs. Roy' chrysanthemum flowers developed from buds left on plants and from cut buds opened in water or in opening solution*

Buds opened on plant, buds opened in solution, and buds opened in water	Diameter after [1] [2]—		
	2 days	4 days	7 days
	Mm.	*Mm.*	*Mm.*
Opened on plant	71 c	118ab	133a
Harvested and held in opening solution [3]	111 b	123ab	126ab
Harvested and held in water [4]	97	109	—

[1] Initial flowerbud dimaeters were 50 to 55 mm.
[2] All means are significantly different at the 1-percent level when followed by different letters.
[3] Opening solution: 200 p.p.m. + 2-percent sucrose.
[4] Flowers held in water were not included in statistical analysis since vase life was terminated at 7 days. Means at 2 and 4 days for this treatment are included for numerical comparisons only.

DISCUSSION

These experiments show that under the appropriate conditions, chrysanthemum flowers can be harvested in the bud stage and successfully opened. It was necessary to use sucrose in the opening solution to obtain maximum flower diameter and fresh weight. Flowers held in 8–HQC plus sucrose were consistently larger, heavier, and had better form than flowers held in water. The optimum concentrations were 200 p.p.m. 8–HQC and 2-percent sucrose. No advantage was gained from using higher levels of 8–HQC or sucrose. The tests indicate that buds cut when 50 to 60 mm. in diameter require a 6- to 7-day opening period at 74° F. before flowers are commercially acceptable. Although buds could be harvested when as small as 30 mm. in diameter, flower size was smaller than for buds harvested at 60 mm. in diameter. Flowers held in 8–HQC plus sucrose always developed chlorotic foliage. Chlorosis occurred 10 to 18 days after the flowers were in solution, depending on the season. Chlorosis was found to be associated with the sucrose rather than with quinoline. In spite of the chlorosis, use of 8–HQC plus sucrose or a preservative prevented foliage from wilting whereas water did not. Stems held in 8–HQC-sucrose always developed discolored stems. Discoloration occurred only on the part of the stem that was in the solution.

Light intensity or duration did not have as great an influence as opening solution on the development of chrysanthemum flowers. As little as 75 ft.-c. of light was sufficient for successfully opening bud-cut flowers. Light intensity or duration during development had no influence on flower vase life. The influence of darkness on flower development was not evaluated in these studies, but should be assessed in future experiments.

The effectiveness of 8–HQC plus sucrose as an opening solution and flower preservative was repeatedly shown. Increased development and longevity has been noted on other cut flowers held in 8–HQC plus sucrose *(7, 8, 9, 10,* and *11).* Possibly, the mechanism for increasing longevity in chrysanthemums is similar to that suggested for roses *(2) (11)* and gladiolus *(10).* It has been suggested that 8–HQC inhibits vascular blockage and allows greater solution uptake in roses. In these experiments, chrysanthemum flowers held in 8–HQC plus sucrose absorbed more liquid than flowers held in water. Also, sucrose has been shown to cause stomatal closure in roses *(11)* and gladiolus *(10).* Possibly, a similar mechanism exists for bud-cut chrysanthemums.

All chrysanthemum cultivars do not respond similarly to 8–HQC sucrose mixture, although most of those tested did develop further in 8–

HQC sucrose. 'Explorer' did not open well in 8–HQC sucrose, but flowers had better form than those held in water. 'Indianapolis White' stems broke after being held in 8–HQC sucrose for 10 days. Stem breakage was caused by the increase in flower head weight induced by the opening solution. Subsequent experimentation showed that 'Indianapolis White' flowers grown as single stems did not break and were superior in opening ability to flowers grown as branched plants. These data indicate that treated specimens must have stronger stems and suggest that physical characteristics of our present chrysanthemum cultivars will have to be evaluated before this technique is used commercially.

The dry storage techniques utilized by Fischer *(3)* and Mastalerz *(12)* appear to be adaptable to chrysanthemum flowerbuds. Flowers harvested as buds and stored dry at 31° F. opened as well as freshly harvested buds. However, for maximum flower development and longevity, stems had to be held in 8–HQC plus sucrose after storage. Since vase life of bud-cut flowers was only slightly less than vase life of open flowers, storing chrysanthemum flowers in the bud stage appears to be within the realm of commercial practicality. Flower growers or wholesalers could store chrysanthemum flowers in the bud stage for peak demands, or store and open flowers when marketing conditions were especially favorable.

Flowers harvested as buds and developed in opening solution were as large as flowers allowed to develop on the intact plant (table 18), but greenhouse temperature was not accurately controlled. During the early phase of development, greenhouse temperature was considerably lower than 62° F., night temperature. Since temperature is known to influence flower form and diameter *(13)*, it would be well to thoroughly evaluate the effect of greenhouse temperature on flower opening before making general statements. Evidence here suggests that during cool or inclement weather, flower growers could harvest flowers in the bud stage and open them off the plants. This technique would make it possible to prepare production schedules that were more accurately timed and not wholly dependent on weather. Such scheduling would be particularly important in field production of chrysanthemum flowers.

The technique of opening chrysanthemum flowerbuds off the plant appears to be sufficiently promising to warrant further exploration for commercial application. The savings in transportation costs, ease of harvesting, and reduced damage to the flowers are economically important factors to flower growers. Further study of factors relevant to opening chrysanthemums off the plant and to commercial shipments should be conducted to develop methods of practical utilization.

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