THESIS

HARVESTING AND HANDLING OF CARNATIONS AS TIGHT BUDS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY LE-HONG CHENG

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CHAPTER 1

INTRODUCTION

The carnation market is highly competitive and becomes more so each year. To compete, growers must deliver to customers carnations of superior quality at competitive prices. The major requisite of quality is long cut-flower life. A reliable preshipping treatment for carnations would decrease shipping loss and consumer dissatisfaction. In recent years, carnation preservatives for extending cut-flower life have become popular on the market.

Carnations are typically cut when the flowers are fully open. They are also shipped and stored in this condition (7). Several other flower crops are successfully cut and shipped before the flowers are open (10, 16, 25, 28). In 1960 Kohl and Smith (14) first suggested that it could be advantageous to cut carnations in the bud stage. Carnation buds showing 1/4 inch to 1 inch of petals were used in their experiments. For successful use of this technique, Kohl and Smith suggested the use of a good preservative solution and 70F as a minimum opening temperature. The objectives of this study were to determine the most desirable preservative and to find a practical method to ship and store carnations as tight buds.

Possible advantages in harvesting carnations as tight buds are:

1. They are removed from plants as much as a week earlier, thereby starting the next crop sooner.

2. The flowers are opened in a controlled environment to avoid possible damage from variability in light and temperature common in a greenhouse.

3. The space required for storage or shipment is reduced.

4. Possible petal damage caused by frequent handling of open blooms is minimal.

5. It might be possible to ship carnation buds in storage from one part of the world to another and open them near terminal markets. One possible disadvantage is the difficulty involved in grading the buds and bunching them so they open the same day.

Six experiments were performed in an attempt to answer these questions:

1. What kinds of solution are satisfactory for opening carnation buds off the plant?

2. What life can be expected from flowers opened from buds if they are placed in water or in different solutions? This comparison was made with flowers opened on the plant as a control.

3. What is the best opening room temperature?

4. What is the most satisfactory stage of buds for opening and performance?

5. What is the difference between open flowers and buds in their reaction to shipping?

   a. at different temperatures?

   b. for different times?

6. What are the effects of dry storage for 3 weeks on open blooms and bud stages 1, 2, and 3 as defined in Experiment 4?

CHAPTER II

LITERATURE REVIEW

The factors that influence post-harvest life have been the subject of research for many years. Only the results of investigations directly related to the problems of harvesting flowers in the bud stage are reviewed here.

Stage of Bud Development

The life of cut flowers has been affected by the stage of the development or the time of cutting (19). The flowers of several crops have been successfully cut in the tight-bud stage (10, 16, 25, 28).

In 1960 Kohl and Smith first suggested cutting carnations before they were fully opened. They found that these flowers were similar in quality and useful life to those cut at the usual open stage (14). Kuc and Workman (15) showed that open carnation flowers had better keeping life and appearance than buds when put in the water but they did not use a flower preservative in their experiment. After preliminary tests, Holley concluded that carnation buds showing one-half inch of color, or more, could be dry stored and opened off the plant with good results. The solution used for opening and keeping flowers was important (8). Cutting carnations in a tight bud stage can reduce the amount of petal burn compared to those opened on the plant (11, 12).

Time of Cutting

Carnation flowers contain more respirable foods in the late afternoon than early in the morning. Therefore, the time of cutting could affect the keeping life. The effects of cutting on keeping life

have been studied extensively. Cutting in the afternoon is reported to be better, both in keeping life and in avoiding petal burn (12, 13, 19, 23).

Dry Cold Storage

Long-term storage of cut flowers facilitates a balance of supply and demand. To be economically feasible, flowers from storage should keep and perform equal to freshly cut flowers.

Neff and Loomis (20) packaged marigolds in waxed paper and stored them at 33 and 40F without placing them in water. These dry-stored flowers kept better at room temperature than those stored at the same temperature with stems in water for the same period. Neff (21) found that carnation flowers also kept better in dry cold storage. Carnations, stored dry at 33F for 39 days, kept almost as well as freshly cut flowers. The better keeping quality in dry storage was attributed to the low turgor pressure preventing the development of the flowers (20, 21, 26). The low temperature reduced respiration (20, 21, 26). Other workers have obtained similar results with several cut flowers (2, 3, 9, 12, 18, 24, 26).

When cut flowers were removed from dry cold storage, the stems were recut and placed in warm water at a temperature of 100F or higher. These two treatments increased water uptake and retention (18, 26).

Chemical Treatment of Cut Flowers

The desire to keep flowers fresh as long as possible is inherent to the idea of cut flowers. One endeavors to keep flowers fresh on the one hand by harvesting at an early age and controlling the environment during storage. On the other hand, cut-flower life can be lengthened by

modifying the solution in which the cut flowers are placed. Only the results in which chemical methods are used are discussed here.

Using chemicals in water is probably the most practical method of extending the life of cut flowers. Tests involving use of chemicals in water to preserve keeping quality of flowers go back over 50 years. During this period, many types of chemicals have been studied, including bactericides, fungicides, sugar, mineral salts, respiration inhibitors, and drugs, such as acetylsalicyclic acid. The use of aspirin has been reported useless, or even damaging in most cases (1, 5).

About the end of World War II, a new group of "flower preservatives" began to appear on the market. These preservatives contained sugar and other chemicals to control microorganisms and reduce respiration (1, 26, 27).

Sugar provides a carbohydrate source for respiration. Most of the sugar supply disappears from the flower petals 48 to 72 hours after cutting (19). When sugar is not available, the proteins within the flower tissues are used as a source of energy and a main by-product formed in the flower petals is ammonia. When large amounts of ammonia accumulate they cause rapid death (19, 31). The optimum amount of sugar varies with varieties and with time of year. Sucrose appears to be the best sugar to use, although glucose is equal to sucrose in most cases. Other sugars are not as effective as sucrose or glucose (1, 29). The addition of sugar alone without a chemical to prevent growth of microorganisms may do more harm than good (1, 3, 4, 7, 27, 29).

Antimicrobial substances are used to prevent plugging of the vascular system of flower stems. When the stem of a flower is cut, the contents of the cells at the base of the stem escape into the water

of the vase. The released cellular contents are available for the nutrition of numerous organisms and their consequent metabolic products result in plugging of the water conduction vessels, thereby reducing the rate of water uptake (1, 17).

Silver salts at concentrations of 1 to 4 ppm have been the most effective compounds for controlling microorganisms without harming flowers. Heavy metal ions such as copper, zinc, iron, and strontium also have value in this respect (1, 5, 17, 27, 29).

Scholes (29) reported that copper sulfate, 8-quinolinol sulfate, silver acetate, and silver nitrate were the only chemicals used in his study that effectively controlled microorganisms. Copper ions controlled only the growth of bacteria. Other chemicals are needed to control fungi. Concentrations of 8-quinolinol sulfate at 200 to 1,000 ppm completely inhibited microbe growth. Zentmyer (32) found a concentration of 100 ppm of 8-quinolinol sulfate completely controlled microorganisms in water. At 200 ppm there was little or no toxicity noted. However, the concentration of this chemical, if too high, will cause damage to the stems that resembles damage caused by microorganisms.

In some instances, even if the growth of microbes is prevented by chemicals, natural plugging can occur. According to Aarts (1), this plugging appeared to be a result of substances secreted by the disorganized cells at the cut surfaces. It was an aerobic process. Calcium nitrate or citric acid were good chemicals for preventing this natural blocking of the vascular system (1).

Metallic salts also tend to increase or maintain flower color (22).

CHAPTER III

METHODS AND RESULTS

General Method and Procedures

This investigation was limited to the varieties Red Gayety and Scania. Red Gayety was cut from the Colorado State University Greenhouses; and Scania was obtained from Davis Brothers Florists, Inc., Denver, Colorado, in dry pack. A minimum of 12 flowers was used for each treatment. Buds were cut at a stage with 1/2 to 3/4 inch petal exposed. These flowers were cut from the same bench on the same day and recut to standard grade length. Open blooms were put directly in the solution to be tested in the keeping room. Buds were put in the opening room and moved to the keeping room after opening. The keeping room was a laboratory where temperature was variable. Temperature and relative humidity were recorded in this room for each test period. The opening room was controlled to $\pm$ 1F. Solutions under test were not renewed during the life of the flowers, although some water was added if absorption by the flowers made it necessary. Glass containers were used in the keeping room and plastic containers in the opening room. Containers were cleaned with detergent and water before each test.

Useful life was measured from the day the flowers opened until petals lost their turgor, collapsed, or lost their decorative value because of severe petal burning. The life was recorded as one day before this stage was reached. In each experiment, comparisons were made with flowers opened on the plant. Analyses of variance and least significant differences (LSD) were computed.

Experiment 1

Everbloom, a recently introduced cut flower preservative, gave outstanding results on carnations (7). The collapse of some of the stems during these tests was attributed to the high concentration of Everbloom. Cornell solution[1] was best in extending the life of Velvet Times Rose (29). To determine the best solution and concentration for opening carnation buds, a series of experiments were conducted. Advanced buds showing a half inch of color or more were used in these experiments.

A. Different combinations of Everbloom at 40, 50, and 60 grams per liter and Cornell solution were used in the opening and keeping rooms. From October 3, 1963, to October 28, 1963, carnation buds were cut and opened in solutions containing 50 and 60 g/l Everbloom and in Cornell solution. As the buds opened, the flowers were tagged with date and kind of opening solution and moved to keeping solutions. Before October 18, 50 g/l Everbloom solution was used in the keeping room. This concentration was apparently too high for flowers opened in Everbloom solution, since 50 per cent of the flower stems collapsed. The keeping solution was reduced to 40 g/l Everbloom. There were six combinations as follows:

	Opening Room	Keeping Room
1.	Everbloom 60 g/liter	Everbloom 50 g/liter
2.	Everbloom 60 g/liter	Everbloom 40 g/liter
3.	Everbloom 50 g/liter	Everbloom 50 g/liter
4.	Everbloom 50 g/liter	Everbloom 40 g/liter
5.	Cornell solution	Everbloom 50 g/liter
6.	Cornell solution	Everbloom 40 g/liter

[1]Cornell solution is the preservative used by Scholes (29). It contains 200 ppm 8-quinolinol sulfate, 50 ppm silver acetate, and 5 percent sugar.

The opening room temperature was 70F, and mean relative humidity was 64 per cent. The keeping room mean temperature was 73F, varying from 59 to 80, and mean relative humidity was 26.5 per cent.

The use of Cornell solution in the opening room increased cut flower life and decreased petal burning, when compared to Everbloom. The differences (Table 1) were highly significant. A concentration of 50 g/l Everbloom in the keeping room was too high for flowers opened in Everbloom, causing the collapse of 50 to 53 per cent of these flower stems during the keeping period. Flowers in Everbloom 40 g/l solution did not break over; however, some collapse of the lower part of the stems was observed. Flowers opened in Cornell solution did not collapse. Cornell solution in the opening room and Everbloom in the keeping room (50 or 40 g/l) gave best results.

Experiment 1B

Carnation buds from dry storage were compared with those opened immediately.

On January 21, 1964, open flowers and buds were cut in Denver and shipped to Fort Collins the same day. Half of the buds were dry stored in 33F and half were opened immediately in two solutions: Cornell solution and 40 g/l Everbloom solution. These two solutions were used in the keeping room also. After two weeks, buds were taken from storage, the stems recut, and opened in the two solutions before transfer to the keeping room. Twenty-five blooms opened on the plant were placed in Cornell solution, and 25 in 40 g/l Everbloom solution to establish the life of control flowers. There were 14 combinations in this experiment (Table 2).

Table 1: The differences in days of useful life, time to petal burning and breaking over of Scania buds in different opening and keeping solutions.

Treatments	Opening room solution	Keeping room solution	% petal burning	Days to petal burning	% breaking over	Useful life
1	Ever. 60g/liter	Ever. 50g/liter	66.00	8.40	50	9.43
2	Ever. 60g/liter	Ever. 40g/liter	100.00	4.14	-	9.00
3	Ever. 50g/liter	Ever. 50g/liter	82.35	8.00	53	9.94
4	Ever. 50g/liter	Ever. 40g/liter	86.00	6.62	-	10.00
5	Cornell	Ever. 50g/liter	63.00	11.00**a	-	11.50**a
6	Cornell	Ever. 40g/liter	91.66	9.15**a	-	11.30**a

a/ significant at the 1% level

Table 2: Fourteen different combinations of Everbloom and Cornell solutions in opening and keeping rooms for open blooms, buds opened immediately and buds 2 weeks in dry storage.

		Preservative at Opening room	Keeping room
1.	Flowers opened on plants	-	Cornell solution
2.		-	Everbloom 40 g/l
3.	Buds opened immediately	Cornell solution	Cornell solution
4.		Cornell solution	Everbloom 40 g/l
5.		Everbloom 40 g/l	Cornell solution
6.		Everbloom 40 g/l	Everbloom 40 g/l
7.	Buds 2 weeks in dry storage	Cornell solution	Cornell solution
8.		Cornell solution	4/5 Cornell solution
9.		Cornell solution	Everbloom 40 g/l
10.		Cornell solution	Everbloom 30 g/l
11.		Everbloom 40 g/l	Cornell solution
12.		Everbloom 40 g/l	4/5 Cornell solution
13.		Everbloom 40 g/l	Everbloom 40 g/l
14.		Everbloom 40 g/l	Everbloom 30 g/l

Opening room temperature was 75F, with relative humidity about 65 per cent. The keeping room mean temperature was 68F, varying from 55 to 79F. Relative humidity varied from 10 to 25 per cent.

Table 3 contains the results in which flowers opened on the plant are compared with buds opened immediately and buds stored two weeks.

The useful life was not significantly affected by stage of maturity. In general, the use of Cornell solution in the opening room and Everbloom as a keeping solution were superior to other combinations. Cornell solution in both opening and keeping rooms gave inferior results.

A concentration of 40 g/l Everbloom was too strong for flowers opened on the plant or buds stored two weeks, but did not damage unstored buds. This differential effect is not understood.

The greatest useful life (13+ days) was obtained when stored buds were opened in Cornell solution and Everbloom was used in the keeping room. Everbloom used in both solutions gave best results (13+ days) with unstored buds.

The use of Cornell solution in both opening and keeping rooms for buds stored 2 weeks decreased flower size and color. The size and appearance of flowers in all other treatments were similar.

Experiment 1C

The optimum concentration of Everbloom solution for the keeping room was determined. For practical use, it is inconvenient to weigh Everbloom. Flowers opened on the plant were placed in Everbloom solution at concentrations of 2, 3, and 4 tablespoons/quart (1 tbs of Everbloom weighs 13.5 grams). Useful life of these flowers was 10.9, 12.0, and 11.0 days, respectively. None of the stems of these flowers in 2 or 3 tbs/qt collapsed during the keeping test.

Cornell solution was used in the opening room and 3 tbs/qt Everbloom solution in the keeping room in the following experiments.

Table 3: Comparison of differences in useful life, petal burning, and breaking over in different preservative combinations in the opening and keeping rooms. Experiment 1B

Treatment	Type of flowers	Opening room	Keeping room	% petal burning	Days to petal burn	% breaking over	Useful life in days
1	Cut open	-	Cornell	52.00	10.80	-	12.00
2		-	Ever. 40g	96.15	10.12	80	10.30
3	Buds open immediately	Cornell	Cornell	27.27	9.90	-	9.75
4		Cornell	Ever. 40g	100.00	9.50	-	11.36
5		Ever. 40g	Cornell	58.33	9.85	-	10.83
6		Ever. 40g	Ever. 40g	92.00	10.47	-	13.40
7	Buds dry storage for 2 weeks	Cornell	Cornell	9.00	10.00	-	8.63
8		Cornell	4/5 Cornell	7.70	10.00	-	7.54
9		Cornell	Ever. 40g	84.61	11.45		13.70
10		Cornell	Ever. 30g	72.72	10.63	-	13.66
11		Ever. 40g	Cornell	90.90	9.70	9.00	11.54
12		Ever. 40g	4/5 Cornell	92.30	10.16	15.40	11.30
13		Ever. 40g	Ever. 40g	75.00	9.30	100.00	6.26
14		Ever. 40g	Ever. 30g	23.00	10.70	92.00	7.85

Experiment 2

To estimate the performance of flowers opened off the plant and placed in several preservatives and in water, buds were cut and opened in Cornell solution on two dates. Equal lots were placed in water, Floralife[1], Petalife[2], Everbloom (3 tbs/qt), and Cornell solution in the keeping room. The concentrations of Floralife and Petalife were according to the manufacturer's directions. Flowers opened on the plant were placed in the five solutions as controls. In the first test, mean temperature in the keeping room was 66F, varying from 55 to 89; mean relative humidity was 35 per cent. In the second test, mean temperature was 66F, and mean relative humidity was 28 per cent.

There was a highly significant difference in size and useful life of flowers opened on or off the plant when placed in different preservative solutions in the keeping room. The use of Everbloom and Cornell solutions resulted in larger flowers and longer useful life than Floralife or Petalife (Table 4). The effects of Everbloom and Cornell solutions were not significantly different.

Flowers opened off the plant had longer useful life in Petalife and Floralife than those allowed to open on the plant. Color of flowers kept in Petalife or Floralife was not as bright as those in Cornell or Everbloom solutions. Differences in size between flowers opened on the plant and those opened off the plant were not significant in any of the solutions.

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[1]Floralife is a cut flower food from Floralife, Inc., Chicago, Ill.

[2]Petalife is a cut flower preservative from Park-Elitch Co., Denver, Colorado.

Table 4: The size and useful life of carnation flowers opened on and off the plants in different preservatives. Flowers opened off the plants in Cornell solution.

		Floralife		Petalife		Everbloom		Cornell		Water	
		Open	Buds	Open	Buds	Open	Buds	Open	Buds	Open	Buds
Flower size	Rep. 1	7.38	7.71	7.21	7.73	8.21	8.21	8.43	8.59	6.99	-
	Rep. 2	7.92	7.84	7.69	7.86	8.69	8.61	8.45	8.55	7.51	7.63
	Mean	7.65	7.78	7.45	7.80	8.45	8.41	8.44	8.57	7.25	7.63
Useful life	Rep. 1	9.60	10.53	7.87	10.47	16.13	16.67	14.20	15.00	6.80	-
	Rep. 2	8.80	10.13	8.47	10.53	15.53	16.07	15.13	14.73	5.55	7.67
	Mean	9.20	10.33	8.17	10.50	15.83	16.37	14.67	14.87	6.18	7.67

LSD (0.01) in flower size = 0.671

LSD (0.05) = 0.4612

LSD (0.01) in useful life = 3.5145

LSD (0.05) = 2.283

Experiment 3

To determine the best opening room temperatures, two constant temperatures were adjusted to 75 and 80F for one test and to 70 and 75F for a second test.

Advanced buds of Red Gayety were opened on January 28 for the first part and on February 6 for the second part. These were opened in Cornell solution and placed in the Everbloom solution (3 tbs/qt) in the keeping room.

Mean keeping room temperature was 65F, with mean relative humidity 35 per cent for the first test. During the second test, mean temperature was 68F and mean relative humidity 31 per cent.

There were no significant differences in flower size and flower color between flowers opened at 80F and those at 75F. Flowers opened at 75F had longer useful life. When buds were opened at 70 and 75F, differences in flower size, color or useful life were not significant. Either 70 or 75F produced good opening results.

Table 5: The useful life and flower size of Red Gayety flower buds opened at three temperatures (Experiment 3).

	Opening room temperature		
	80F	75F	70F
Flower size	11.3 cm	11.4	
Useful life	12.83 days	15.50[a]	
Flower size		10.63	10.36
Useful life		13.00	13.42

a/ Significance at 0.01 level, using simple t test.

Experiment 4

To determine effect of stage of bud development at harvest on size and appearance of flower, petal burning, and cut flower life, carnations were cut at four different stages of development on December 1, 1964. These stages ranged from tight buds to open blooms (bud stages shown in Figure 1). The buds were opened in Cornell solution at 75F and moved to the keeping room in Everbloom solution (3 tbs/qt). Mean keeping room temperature was 67F, with mean relative humidity 24.5 per cent.

Table 6: Definition of the bud stages, based on amount of petal color showing.

Bud stage	Amount of petal color showing
1	1/4 inch
2	1/2 inch
3	3/4 - 1 inch

Flowers from bud stage 1 were lighter in color. Differences in size and useful life (Table 7) were not significant. No petal burning or breaking over of stems was shown in these treatments. At 75F opening temperature, bud stages 1, 2, and 3 required 4.2, 2.9, and 2.2 days to open, respectively.

Table 7: The useful life and flower size of open blooms compared to flowers opened off the plant from bud stages 1, 2, and 3.

	Open blooms	Bud stage 1	Bud stage 2	Bud stage 3
Flower size /1	11.00	10.84	11.08	11.90
Useful life /2	15.83	17.00	17.00	16.73

/1 Diameter in cm

/2 Mean life in days

Experiment 5

Buds were compared with open flowers in their reaction to shipment at different temperatures for different times. Both open blooms and buds were divided into eight categories.

Fig. 1. A comparison of bud stage 1, bud stage 2, and bud stage 3. Top photograph shows (L-R) bud stages 3, 2, and 1. Bottom shows (L-R) stages 1, 2, and 3.

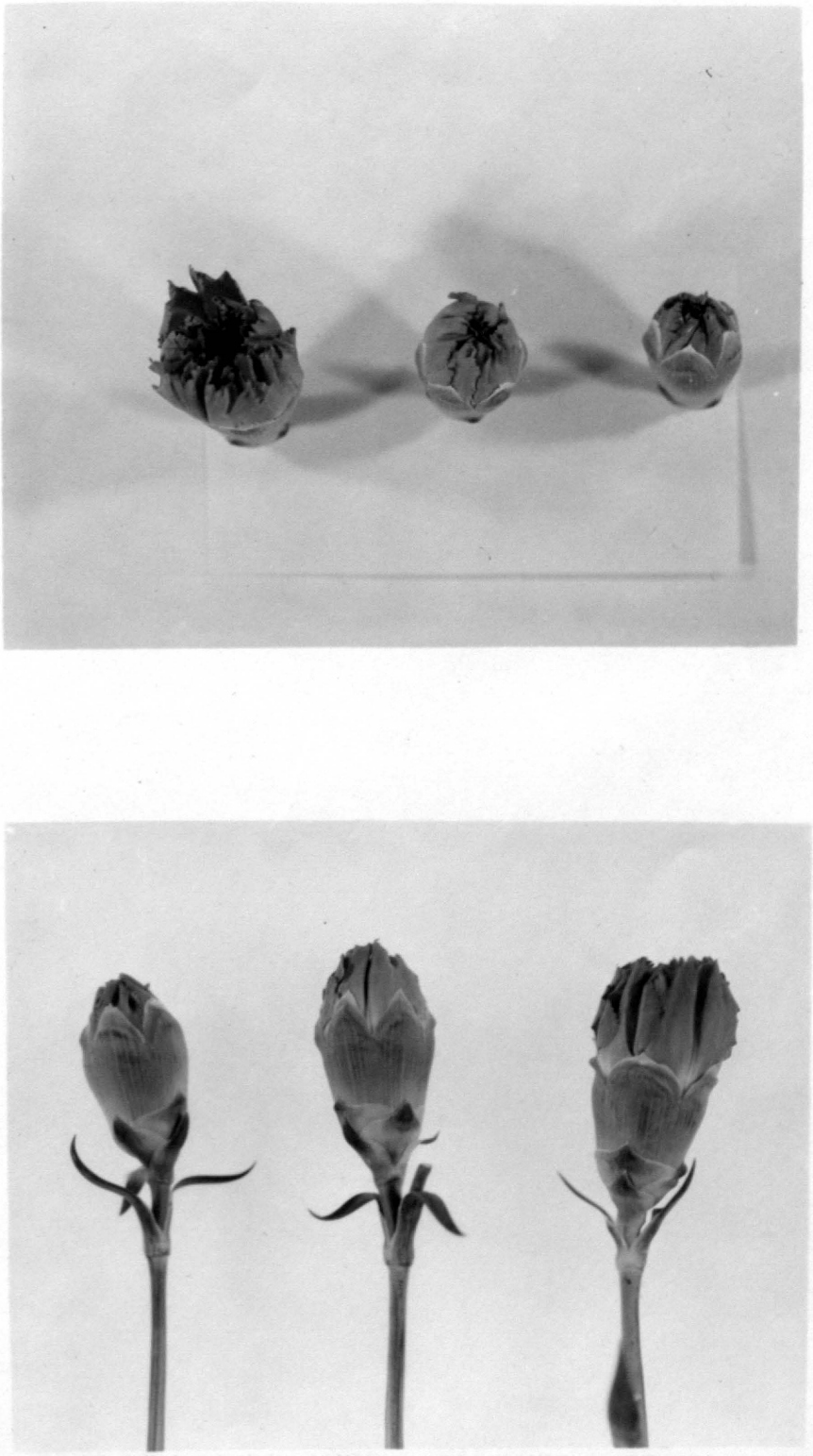

Fig. 1. A comparison of bud stage 1, bud stage 2, and bud stage 3. Top photograph shows (L-R) bud stages 3, 2, and 1. Bottom shows (L-R) stages 1, 2, and 3.

a. Control not shipped

b. Shipped 24 hours at 75F

c. Shipped 48 hours at 75F

d. Shipped 72 hours at 75F

e. Shipped 72 hours at 50F

f. Shipped 72 hours at 40F

g. Shipped 48 hours at 50F, then changed to 75F for 24 hours

h. Shipped 48 hours at 40F, then changed to 75F for 24 hours

Buds and open blooms were cut in Denver, Colorado, on January 12 and shipped to Fort Collins. On January 14, equal lots of these were packed for simulated shipment in 40, 50, and 75F temperatures. After 24, 48, and 72 hours, samples of buds and open blooms were removed from each temperature, and stems were recut. Buds were opened in Cornell solution at 75F. Cut flower life was measured in Everbloom solution (3 tbs/qt). Mean keeping room temperature was 63F; and mean humidity, 35 per cent.

Time: There was no statistically significant difference in useful life of buds and open blooms not shipped, or shipped 24 or 48 hours at 75F (Table 8). The life of open blooms decreased with time in shipment, the difference becoming significant with the 48-hour shipment. When buds were shipped 48 hours, the life of the flowers was not significantly decreased.

Both open blooms and buds shipped 72 hours at 75F were damaged severely. Nearly all open blooms lost their commercial value. More than half of the buds failed to open. Buds withstood this stress much

better than the open blooms.

Differences in flower size between buds and open blooms, and between all except the 72-hour shipment, were not significant. Flowers shipped 72 hours were so poor that measurements were not reliable.

Color of flowers shipped 24 hours was as good as open blooms. The flower color of both buds and open blooms became deeper and duller as time in shipment increased. Amount of petal burn developing on the flower was not affected by shipping time.

Temperature: There were no significant differences in useful life between open blooms and buds in three of the shipping temperatures (Table 9). Open blooms shipped at 50F kept longer than buds shipped at this temperature. Raising the temperature to 75F the last 24 hours in shipment decreased the life of open blooms significantly. The effects of this higher temperature on buds were not significant.

Table 8: The useful life (days) of Scania carnations opened on and off the plants after 24, 48, or 72 hours shipping at 75F.

	No Shipping		Shipping					
			24 hours		48 hours		72 hours	
	Open	Buds	Open	Buds	Open	Buds	Open	Buds
Useful life	16.10	16.00	15.33	13.80	13.00	14.20	2.17	8.33

L. S. D. (0.01) = 3.09

L. S. D. (0.05) = 2.32

Table 9: The useful life in days of Scania carnations opened on and off the plants after shipping at four temperatures for 72 hours.

	Shipping 72 hours at							
	50F		40F		40-75F		50-75F	
	Open	Buds	Open	Buds	Open	Buds	Open	Buds
Useful life	17.6	14.3	15.5	13.3	12.4	12.5	12.5	13.0

L. S. D. (0.01 = 3.75

L. S. D. (0.05) = 2.84

Experiment 6

Effects of dry storage for 3 weeks on open blooms and three bud stages were compared. Open blooms and bud stages 1, 2, and 3 were cut on December 1, and packed in a polyethylene lined shipping box. These were stored at 33F for 3 weeks, removed from storage, the stems recut, and placed in 100F warm water for 4 hours. Previous procedures for opening the buds and measuring cut flower life were followed. Mean temperature in the keeping room was 65F, and mean relative humidity was 35 per cent.

All bud stages opened satisfactorily following 3 weeks of dry storage and kept significantly longer than flowers opened on the plant. Color and size were similar in the four treatments. No one bud stage was superior.

Table 10: The useful life of flowers opened on the plants compared to bud stages 1, 2, and 3 opened off the plants after 3 weeks cold dry storage.

	Open blooms	Bud stage 1	Bud stage 2	Bud stage 3
Useful life	16.33	17.33	17.42	17.58

L. S. D. (0.05) = 0.446

CHAPTER V

DISCUSSION AND SUMMARY

The purpose of this study was to investigate the performance of carnations harvested as tight buds, and to find the best solutions for opening the buds and keeping the flowers at room temperatures. The effects of stage of bud development and opening temperatures on quality and life of the flowers were also studied. Finally, the reaction of buds and open blooms subjected to the stress of long term storage or shipment was compared.

Since the preservative for opening or keeping the flowers was of primary importance (8, 14), the better commercial mixtures were compared with Cornell solution. Everbloom and Cornell solutions were highly superior as keeping solutions to Petalife and Floralife. Although the use of Everbloom resulted in greatly extended flower life, stem collapse and breaking was a problem. The termination of useful life for flowers in Everbloom was accompanied by severe petal burning and breaking over of the stems. After 3 to 5 days in this solution collapse began at the base of stems and gradually progressed upward. Flowers remained turgid even when most of the stems had collapsed. The severity of stem collapse was associated with concentration, and possibly with time of year. Concentration of Everbloom in solution affected stem collapse more than useful life (Experiment 1C).

When Cornell solution was used in the keeping room, flower life ended with loss of turgor and wilted petals. Stems did not collapse in Cornell solution. There was no advantage to reducing the concentration of Cornell solution (Experiment 1B). The final wilting of flowers in

Cornell solution may have been due to the blocking of the vascular system. While the reason for this is unknown, it could have been due to silver precipitation. Additions of calcium nitrate can reduce precipitation of silver (30). Details of this await further study.

The two best solutions were tested in all combinations for both opening and keeping solutions. When Cornell solution was used both to open the buds and keep the flowers, useful life was less. When Everbloom was used in both solutions, stem collapse and petal burning limited the useful life of the flowers. A combination of Cornell solution for opening the buds and Everbloom in the keeping solution resulted in longest useful life. When buds are opened in Cornell solution it should be possible to increase the concentration of Everbloom to gain extended life of flowers without damage to the flower stems or petals.

The storage life of buds was equal to that of open blooms for storage periods up to 3 weeks. The effects of storage periods longer than 3 weeks were not investigated.

Under good shipping conditions (low temperature and short time) buds and open blooms should ship equally well. When stresses of high temperature or long shipping time were added, buds shipped more satisfactorily than open blooms.

The results of this investigation are summarized as follows:

1. Cornell solution should be used for opening the buds and Everbloom solution for keeping the flowers.

2. When these preservatives are used for carnation buds, the useful life, flower size and color are equal to flowers opened on the plant.

3. The minimum size of bud to be cut is one with approximately

1/4 inch of petals exposed. Younger buds than this result in lighter color and smaller flower size when opened.

4. The best opening room temperature was 70 to 75F. The maximum temperature without decreasing flower size was 75.

5. Storage life of buds up to 3 weeks was equal to that of open blooms.

6. Buds withstood stresses of high temperature or time in shipment better than open blooms. When these stresses were minimal, shipping performance was equal.

Suggestions for further study:

1. Investigate the storage life of carnation buds under modified environments for longer periods.

2. Improve opening and keeping solutions by the use of more effective disinfectants and possibly chemical additives such as calcium nitrate.

3. Extend this technique to roses and other floral crops.

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APPENDIX

Table A: One way analysis of variance and orthogonol comparisons of the useful life data in Experiment 1A.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	23693.25		
Total	214	889.75		
Treatments	5	186.54	37.3	11.1**[a]
1,2,3,4 vs 5,6	1	168.79	168.79	50.25**[a]
Residual	209	703.21	3.36	

Table B: One way analysis of variance and orthogonol comparisons of the petal burning data in Experiment 1A.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	12113.09		
Total	169	1565.91		
Treatment	5	448.97	89.79	13.19**
1,2,3,4 vs 5,6	1	379.62	379.62	55.74**
Residual	164	1116.94	6.81	

a/ Single asterisk (*) indicates significance at 0.05 level; double asterisk (**), significance at 0.01 level.

Table C: One way analysis of variance of the useful life data in Experiment 1B.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	27612.50		
Total	241	1956.50		
Treatments	13	855.77	65.83	13.63**
7,8 vs 9,10	1	433.00	433.00	89.65**
9,10 vs 11,12	1	60.73	60.73	12.57**
1 vs 2	1	34.79	34.79	7.2**
3 vs 4	1	29.45	29.45	6.09**
4 vs 6	1	26.90	26.90	5.60**
Residual	228	1100.73	4.83	

Table D: One way analysis of variance and orthogonol comparisons in flower life between carnation buds from dry storage and those opened immediately, Experiment 1B.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Total	241	1250.27		
Treatment	13	623.05	47.93	17.4**
3,4,5,6 vs 7,9, 11,13	1	0.85	0.85	0.31
Residual	228	627.22	2.75	

Table E: Analysis of variance, nested design, of flower size data in Experiment 2.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	1041.35		
Total	15	3.22		
Treatments	3	2.59	0.86	21.5**
Open vs buds in treatments	4	0.15	0.04	0.66
Flowers/type/ treatments	8	0.48	0.06	

Table F: Analysis of variance, nested design, of useful life data in Experiment 2. (Water treatment not included.)

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	2496.50		
Total	15	150.80		
Treatments	3	142.35	47.45	26.96**
Flower type in treatments (open vs buds)	4	7.04	1.76	9.78**
Flowers/types/ treatments	8	1.41	0.18	

Table G: Use simple t test to compare the flower size, and useful life data of Experiment 3.

A. Flower Size: 80F vs 75F

$t = 0.46$

$t < t_{22(0.05)} = 1.717$

There was no significant difference between the flower sizes at 80 and 75F.

B. Flower size: 75F vs 70F

$t = 1$

$t < t_{22(0.05)} = 1.717$

There was no significant difference between the flower sizes at 75 and 70F.

C. Useful life: 80F vs 75F

$t = 2.72$

$2.72 \geq t_{22(0.01)} = 2.508$

There was a significant difference at 0.01 level.

D. Useful life: 75F vs 70F

$t = 0.455$

$0.455 < t_{22(0.05)} = 1.717$

There was no significant difference.

Table H: One way analysis of variance in useful life between open blooms, bud stages 1, 2, and 3, Experiment 4.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	13300		
Total	47	93		
Treatments	3	11	3.67	1.97
Residual	44	82	1.86	

There were no significant differences in useful life.

Table I: One way analysis of variance in flower size between open blooms, bud stages 1, 2, and 3, Experiment 4.

Source	Degree of freedom	Sums of squares	Mean square	F value
Mean	1	5766.28		
Total	47	8.81		
Treatment	3	0.36	0.12	0.6
Residual	44	8.45	0.19	

There were no significant differences in flower sizes.

Table J: One way analysis of variance, nested design, in useful life date of Experiment 5 (time).

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	14677.8		
Total	95	2671.2		
Treatments	3	1697.1	565.7	9.10*
Kind of flowers (open vs buds) treatments	4	248.65	62.16	7.54**
Flowers/kinds/ treatments	88	725.45	8.24	

Table K: Analysis of variance, nested design, of the data from Experiment 5

Source	Degree of freedom	Sums of squares	Mean square	F value
Mean	1	18537.00		
Total	95	1353.00		
Treatment	3	189.75	63.25	
Types/treatments	4	93.08	23.27	2.7
Flower/type/ treatments	88	1070.17	12.17	

Differences not significant.

Table L: One way analysis of variance and orthogonol comparisons in useful life data of Experiment 6.

Source	Degrees of freedom	Sums of squares	Mean square	F value
Mean	1	14145.33		
Total	47	58.67		
Treatments	3	11.67	3.89	3.64*
1 vs 2, 3, and 4	1	11.1	11.1	10.37**
Residual	44	47.00	1.07	

Abstract of Thesis

HARVESTING AND HANDLING OF CARNATIONS AS TIGHT BUDS

Red Gayety and Scania carnations were used to determine the performance of carnations harvested as tight buds. Buds ranged from 1/4 to 1 inch of exposed petal color. 70F and 75F were the best opening room temperatures used. Cornell solution as the opening solution and Everbloom 3 tbs/qt as the keeping solution gave longest useful life. When these preservatives were used for carnation buds, the useful life, flower size, and flower color were equal to flowers opened on the plants. Storage life of buds up to 3 weeks was equal to that of open blooms. Buds withstood stresses of high temperature or time in shipment better than open blooms. When these stresses were minimal shipping performance was equal.