# THE EFFECTS OF LIGHT INTENSITY, FLORAL PRESERVATIVE SOLUTIONS, AND VARIOUS HANDLING METHODS ON FLOWER BUD OPENING AND KEEPING QUALITY OF CUT CHRYSANTHEMUMS

By

JACK CHARLES KURT

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Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Richard N. Payne
Thesis Adviser

W. R. Kays

Robert D. Morrison

D. D. Durham
Dean of the Graduate College

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# CHAPTER I

## INTRODUCTION

Chrysanthemums have traditionally been cut, shipped, and stored when the flowers are fully open. Recently work has been done on the opening of carnations (11, 12, 13, 14, 15), roses (34), and chrysanthemums (23, 27, 28) from the tight bud stage. This provides the possibility for a completely different marketing system for these flowers.

Several advantages appear to be present when handling chrysanthemums in the bud stage. Some of these are: (a) By cutting flowers in the bud stage a grower would be able to produce more crops per year. (b) If a chrysanthemum crop should be early for a holiday period, flexibility in cultural practices could be achieved by cutting in the bud stage, using long-term cold storage and then opening for the holiday period. (c) The crop could be cut when the majority of the crop is at the correct stage of bud development, allowing possible use of mechanical aids for harvesting. (d) The chrysanthemum is simpler to harvest in the bud stage because it is smaller and less likely to get bruised. (e) Shipping costs are reduced if the chrysanthemums are shipped in the bud stage because flowers are shipped by dimensional weight. For example, two and one-half times as many flower buds as open flowers can be shipped in a container (22, 30). (f) There would also be less damage in shipping in the bud stage as compared to the open flower. (g) The prices for flowers during the holiday periods

would be more normal because of the increased supply caused by long-term storage of flower buds (38). (h) There would possibly be lower administrative costs if chrysanthemums were stored and shipped in the bud stage. For example shipments would be less frequent because of larger quantities per shipment and this would result in fewer billings, telephone orders, and other administrative costs (6). (i) Increased flower consumption could result if this new marketing system would reduce the price of fresh cut flowers.

There are several disadvantages, however, with handling the flowers as buds. Some of these are: (a) The florist will need proper facilities for opening the bud-cut flowers. (b) Close cooperation between the growers, wholesalers, and retail florists would be necessary. (c) There would be increased handling for the wholesaler and retailer and it is not known whether they would perform this service.

The implications of this new and yet unexplored marketing system are immense. Laurie, in an article entitled "Changing Times" (22), discussed the idea of wholesalers buying from commercial floriculture producers in Central and South America. Retail florists could, at the same time, bypass the wholesaler and buy in larger quantities directly from the grower (38). The impact on the industry could be called "the floriculture marketing revolution."

The objectives of the study reported herein were: (a) to determine the optimum light intensity for opening chrysanthemum flower buds; (b) to compare bud-cutting with on-the-plant opening of chrysanthemum flower buds in the greenhouse; (c) to determine the optimum method of cutting the basal ends of cut flower chrysanthemums; (d) to find the best flower bud opening solution for cut chrysanthemums; (e) to

determine the optimum concentration and best floral preservative for cut chrysanthemum flowers; and (f) to determine the optimum long-term storage conditions for cut chrysanthemum flower buds.

# CHAPTER II

# LITERATURE REVIEW

## Light Intensity

Lert (23) opened chrysanthemums from the bud stage and found that 50 foot-candles of light intensity was better than light intensity of 5 foot-candles. Work done by Marousky (27) showed that light intensity had little influence on flower opening. He worked with light intensities of 75, 150, and 450 foot-candles. After four days of continuous light exposure, at 75 foot-candle intensity, the flowers were found to be smaller than those in the 150 and 450 foot-candle treatments. Measurements, however, at 7 and 10 days showed no difference in flower diameter. Marousky also stated that light intensity had no effect on cut flower life.

Light improved the quality of chrysanthemum cut flowers (40, 41) by keeping the leaves green and functioning. Additional work by Woltz and Waters (42) showed that light and refrigeration each prolonged cut flower life. Light increased cut flower life by 12% at 45°F and 57% at 75°F. The life of the leaves was increased by 34% by light at 45°F and 240% at 75°F. Since blossoms utilize carbohydrates from the leaves, they were benefited by light to a lesser degree.

At low light intensities, and in darkness, flower petals of chrysanthemums tend to fade (1, 41). The photosynthetic capacity of the leaves was greater up to 400 foot-candles (40). The content of sugar

in the leaves was highest at 400 foot-candles, while at lower light intensities the sugar content in the leaves was very low and the stems supporting the flowers became weak and the stems collapsed. Marousky, working with cut gladiolus, stated that sucrose in solution prevents stem collapse. The sucrose, which was formed by photosynthesis after the flower was cut, prevented the breakdown of other organic compounds (stem pectins) after the natural carbohydrates became depleted.

Woltz (41) stated that one of the limitations of high light intensity is the tendency of the leaves to wilt. He also stated that the intensity of light for opening and storage of cut chrysanthemums should never be so high as to cause excess wilting.

## Stem Cutting

Tincker (37), in reviewing work that had been done by researchers, found different recommendations for cutting the stems of chrysanthemums. It has been stated that crushing the stem at its base allows more water to enter, but it also increases the bacterial and fungal growth. Laurie stated, "A clean cut results in less bacterial action than does snapping or breaking the stem; this tends to increase longevity." Work by Dorner, however, showed that breaking the stems of chrysanthemums was better than cutting the stems.

Tests were conducted comparing uptake of water by chrysanthemum stems cut near the ground vs. cuts in the more succulent area of the stem (30). Flowers that were cut in the more succulent part of the stem lost less weight than those cut near the ground, which shows greater water uptake with cuts in the succulent area. With wilting problems, the chrysanthemums should be cut higher on the stem.

Chrysanthemums also might have harvest injuries similar to roses which cause vascular blockage (21, 30). Recutting the ends of the stems would remove the vascular blockages (bacterial or natural stem blockage) and help increase the water uptake (33). The effect on the cut flower life of chrysanthemums was increased by cutting the stems under the water; however, the trouble involved did not justify the time spent (21, 37).

A series of tests were made comparing cut flower life in different depths of water ranging from ½ inch to 10 inches (21). Results showed the flowers in shallow water lasted as long and sometimes longer than the flowers in the deeper water. There was less bacterial contamination in the shallow water and the absorption of water took place at the base of the stem.

## Floral Preservatives

Marlin Rogers stated in Living Flowers That Last--A National Symposium the following about floral preservatives:

> While the exact recipe of ingredients in each of the materials may not be generally known, most of them are composed primarily of sugar, usually either dextrose or sucrose; an acid substance to reduce the pH of the water; metallic salts to help maintain better petal color, and substances to control the growth of microorganisms in the solution. Some of them, in addition, may contain chemical respiratory inhibitors to slow down the respiration rate of the flowers. (33)

Some of the commercial preservatives were developed for a single species (carnations or roses), while others may be used for most kinds of cut flowers.

Work has been done testing different preservatives used in the opening of immature carnations (13, 14). Holley and Cheng caused immature carnations to open in water, Floralife, Petalife, Everbloom,

and Cornell solution (12). Treatment in Everbloom and Cornell solution had both larger flowers and longer cut flower life than those treated with Floralife and Petalife. Flower color also was brighter using Everbloom and Cornell solution.

Work done by Lert (23) at the University of California demonstrated that all preservative treatments caused chrysanthemum buds to open fairly well. His visual evaluation favored "Everbloom" over a treatment containing 2 per cent sucrose and 200 ppm 8-quinolol sulfate. This treatment was followed by Petalife. Marousky (27) found the best solution for opening chrysanthemum flowers off the plant was 200 ppm 8-hydroxyquinoline citrate plus 2 per cent sucrose. Water and the floral preservatives Bloomlife, FM Super, Roselife, 8-hydroxyquinoline citrate (8-HQC) + Sucrose and Everbloom were used in testing the opening of chrysanthemum flowers off the plant (28). The flowers that were opened in Everbloom and 8-HQC + sucrose had a larger flower diameter and a longer cut flower life than flowers held in the other preservatives and water.

## Sucrose

Sucrose consists of equal quantities of D-glucose and D-fructose. Its molecular formula is $C_{12}H_{22}O_{11}$. Sucrose is considered to be the principal form of translocatable sugar used by higher plants (2).

In floral preservatives, sucrose is usually the major component (2). Its main function is to be a supplement to the endogenous carbohydrate supplies (18, 20). It also increases respiration, decreases transpiration, and delays senescence (2, 25). With roses, the sucrose treatment (4%) caused the respiratory rate to increase 20% the first

day over those treated with tap water and finally by more than 50% (2, 29). This study by Coorts showed that even with an increased respiration rate caused by sugar in floral preservatives, the cut flower life was lengthened.

A sucrose solution decreases water absorption (2, 25, 29). This reduced water uptake is caused by the high osmotic potential of the sucrose solution. Figure 1 shows the reduced water uptake of gladiolus held in water and in a 4% sucrose solution (25).

Another effect that sucrose causes is the closing of the stomates (2, 25, 26). This resulted in a reduction in the transpiration rate. With sucrose-treated roses, the transpiration rate was 30% less than with roses in the tap water-treatment (2). This would, to a certain extent, help delay desication.

Sucrose has no effect on the pH of a solution (19). Without any additive to control microorganisms in the solution, it would be only slightly beneficial (19, 39). After chrysanthemums were held in 4% sucrose solution for 14 days the foliage became chlorotic, while foliage on those in a 2% sucrose solution were only slightly chlorotic (27). Gladioli also showed a slight yellowing of the leaves caused by being in a 4% sucrose solution for 5 days (24).

Chrysanthemum flower buds which were opened in a sucrose solution were found to have a globular form which is typical of flowers opened on the plant, while flowers opened in water were more flattened and had more narrow leaves (27). Sucrose also prevented stem collapse (25). When a plant has been depleted of its natural carbohydrates, it may begin to break down other organic compounds such as stem pectins. This would result in stem collapse.

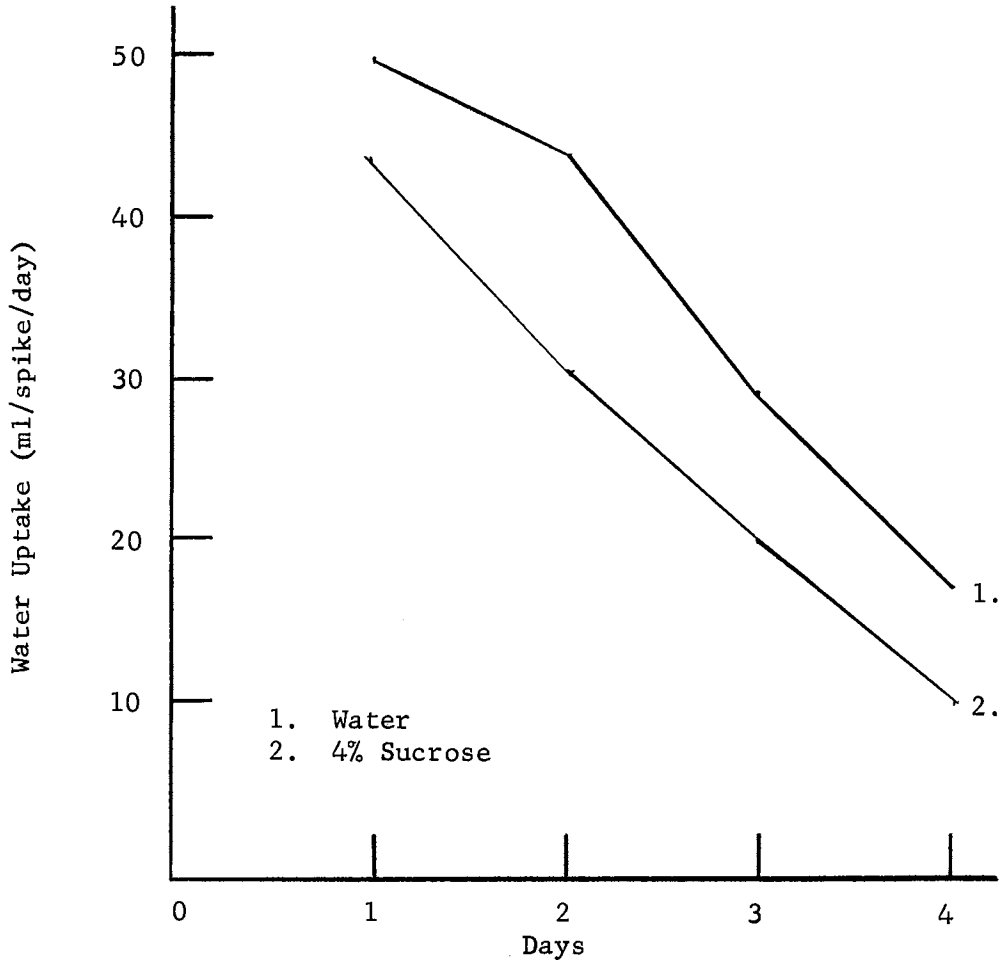


Figure 1. Water Uptake by Gladiolus Held in Water and in a 4% Sucrose Solution

## 8-Hydroxyquinoline Citrate

8-hydroxyquinoline citrate molecular formula is $C_{15}H_{15}NO_7$. Its function in a floral preservative solution is the control of microorganisms (17, 18, 19, 43). Ford (5) at Michigan State University identified the bacteria which were associated with cut flower containers. Work done by Larsen and Cromarty (17) using potato-dextrose agar and type B bacteria agar showed that growth of 34 fungi, 3 yeasts, and 3 bacteria was reduced by using 10 ppm of 8-HQC. At 100 ppm only 5 of the organisms showed any growth. No growth occurred at 300 ppm. A few microorganisms have been isolated in cut flower containers which contained solutions of 300 ppm 8-HQC (19). This showed that 8-HQC might be more effective on an agar medium than in solution in the cut flower container. It is thought, however, that this high concentration (300 ppm) would inactivate the microorganisms in the vase solution (17). This evidence shows that 8-HQC may effectively reduce or eliminate stem plugging and/or production of toxins caused by microorganisms (19).

The use of 8-hydroxyquinoline in quantitative analysis is to precipitate iron and zinc. A theory has been proposed that the material acts as a fungicide by precipitating these elements so that the microorganisms are unable to use them (43). Actual, in-vitro experiments have shown that several fungi will not grow in an 8-hydroxyquinoline concentration of 1-10,000 at a pH of 6.0. When the acidity of the solution is increased to a pH of 3.0 the 8-hydroxyquinoline has no effect on the fungi. This agrees with the fact that the inner complex metal-hydroxyquinoline salts become soluble in strongly acidic solutions.

It is also known that 8-HQC has an effect on the pH of floral solutions. Larsen and Scholes (19) showed that 200 ppm of 8-HQC can with time reduce a solution containing 8-HQC, Alar,[1] and sucrose to a pH as low as 3.7. Three hundred ppm 8-HQC in this solution reduced the pH to 4.8, while 400 ppm 8-HQC had a pH slightly higher than the initial solution pH values of 5.4-6.5. It was shown that 'Better Times' roses and white stock lasted longer at a pH of 4.0 than at a pH of either 6.0 or 2.0 (31). It also has been suggested by Coorts, McCollum, and Gartner that the quinoline compounds act as chelating agents which reduce the physiological plugging in roses (2).

It has been shown that 8-HQC has no influence upon respiration in cut flowers (29).

The use of 8-HQC as a stomatal closing agent has been recognized (18, 25, 29, 36). Larsen and Scholes (18) did recognize 8-HQC as a stomatal closing agent, but they concluded that the increase in cut flower life was caused by the bactericidal properties of the quinoline compounds. It was observed that there was immediate closing of stomata of excised leaves of chrysanthemums when immersed in a solution containing 2000 ppm 8-hydroxyquinoline sulfate (36). A solution of 8-HQC containing 200 ppm for roses and 400 ppm for gladiolus caused stomatal closure (25, 29). This decreased transpiration. Figure 2 shows that a solution containing 600 ppm 8-HQC increased water uptake by gladiolus over plain water (25). It has been observed that cut flowers are ready to be discarded when their present weight is 10% less than was their original fresh weight (2). From this information, one might conclude

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[1]Uni-Royal 85 per cent + W.P. formulation of succinic acid 2,2 - dimethyl hydrazide.

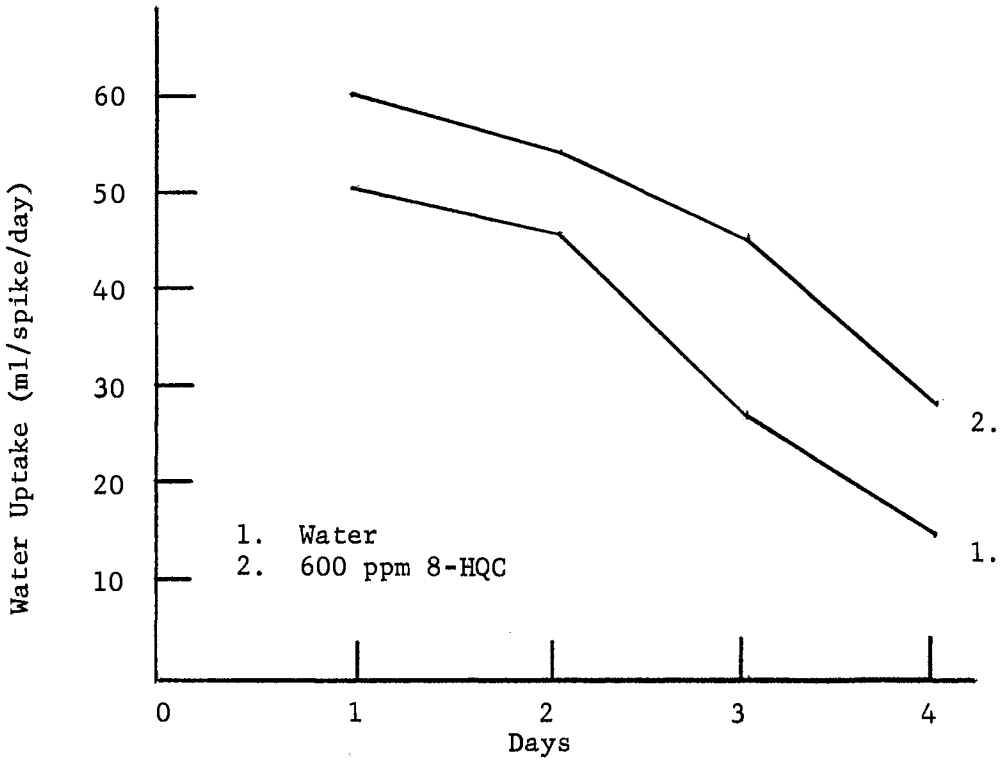


Figure 2. Water Uptake by Gladiolus in Plain Water and in 8-hydroxyquinoline Citrate Solution

that 8-HQC does have an effect on the cut-flower life.

Work by Durkin and Kuc (3) showed that the cut-flower life of roses was shortened by natural stem blockage. Marousky (29), in his work with cut roses, showed that this natural stem blockage was partially overcome by 8-HQC. All of this information supports a theory that 8-HQC does more than control microorganisms, but the mode of action of 8-HQC is still open for speculation (25).

Stem damage occurs on different cut flowers if the concentration of 8-hydroxyquinoline citrate is too high. Mild stem damage occurred at 600 ppm 8-HQC on carnation and at 800 ppm 8-HQC, the stems became desiccated, shriveled and would not support the flower (18). At 500 ppm 8-HQC, the stems of cut stocks would not support the flower (20). With snapdragon treatments of 400 ppm 8-HQC caused stem damage (19).

## N-Dimethyl Amino Succinamic Acid

The molecular formula for N-dimethyl amino succinamic acid (Alar or B-Nine) is $C_6H_{13}N_3O_2$. It has been shown (7, 8, 16, 18, 19, 20) that Alar or B-Nine does increase the cut flower life of various flowers. With cut stocks, the vase life tended to increase slightly with Alar in the water, up to 50 ppm (20). Alar at 500 ppm increased the cut flower life of carnations (18). Larsen and Scholes (8) showed that Alar increased vase-life in only one experiment with snapdragons and then only at 50 ppm. Halevy and Wittwer (7, 8) worked with prolonging the cut flower life of carnations and snapdragons by overnight base immersion (18 hours). This could be done by the grower and its effect would stay throughout the life of the flower.

Alar does have some effect on microorganisms (16, 18, 19, 20). Work has been done with different concentrations of Alar (500, 1000, 2000, 3000, and 4000 ppm) in potato-dextrose and type B bacteria agars to test growth of 34 fungi, 3 yeasts, and 3 bacteria (16). Growth of many organisms was reduced slightly and was reduced further with higher concentrations. Alar actually stimulated growth of a few microorganisms. It is possible that Alar might have more effect on organisms within the flower itself than on artificial media (16). Since the concentrations recommended for stocks and snapdragons (19, 20) are low (10-50 ppm), the Alar probably has only a minor effect on the microorganisms. Use at 500 ppm for carnations (18) and 100 ppm for overnight base immersion for carnations and snapdragons (18) might have a greater effect on the microorganisms.

Petals of cut flowers age faster than the leaves, and this aging is increased after the flowers are cut (8). The two factors which cause aging of flowers are auxin levels and ethylene production. Alar has been shown to slow metabolism and decrease both auxin levels and ethylene production (18, 20).

Alar had an effect on the leaves of cut flowers by the preservation of chlorophyll causing retention of the green color (7, 8). The inhibitory effect of Alar on spike length of stocks (20) was less than the inhibitory effect on cut snapdragons (19). Any concentration of Alar (above 500 ppm) caused phytotoxicity with carnations, but there was no apparent benefit of using Alar above this level (18). Alar caused only a slight decrease in pH (19).

## Long Term Storage

Demand for cut flowers is greatest during the holiday periods. The techniques for long-term storage were developed so that the supply and demand for the holidays might be met. For several weeks before a holiday, a certain number of the daily harvest of cut flowers are stored dry at 31°F (33).

The principal factor for successful long-term storage is the maintenance of 31°F plus or minus 1°F (4, 9, 11, 32, 33). Flower tissue freezes at 29°F and flower deterioration starts to be noticeable at 33°F (32). This is why the 31°F is used as the recommended temperature for long-term storage.

The rate of aging is lower at reduced temperatures (11, 32). At 50°F the rate of respiration is one-half that at 65°F, and at 32°F the rate is about one-half the rate at 50°F. With any temperature below 40° the concentration of ethylene is below the harmful amount. Color change and fading are also controlled by low temperatures in storage. Chrysanthemum flowers held in dry storage at 36 and 44°F were troubled with Botrytis mold invasion (4). At 31°F the growth of fungi is reduced and there is very little mold growth, even after one month storage (4, 32).

Dry storage is best when storing flowers for 2 to 4 weeks (4, 9, 11, 27, 32, 33). The flowers are packaged with the stems not in water. With dry storage, the rate of respiration and flower development are reduced considerably and cut flower life is maintained (33). Water loss occurs until the atmosphere in the container becomes saturated. The container needs to be sealed so that the high humidity in the container does not escape into the atmosphere of the refrigerator.

However, a gas tight seal is not recommended because of toxic carbon dioxide levels. Hall (8), in reviewing literature about $CO_2$, showed that $CO_2$ concentrations in sealed "cellophane" had carbon dioxide build-up to 6.5 per cent. Working with controlled atmosphere storage of carnations, Hanan (10) found that $CO_2$ concentrations above 4% were dangerous.

The containers for storage of cut flowers should be made of material which does not absorb moisture (32, 33). Boxes can be used, but they should be lined with polyethylene. When placing the flowers horizontal in the boxes, care must be used in order to prevent crushing the blooms on the lower layers. If fiberboard drums, plastic garbage cans or metal containers are used for storage, the flowers can be packed upright with the weight on the stem base. One would get less damage from crushing and bruising the flower heads by using upright storage. All boxes and containers should be filled to capacity.

Mastalerz stated in a book edited by Marlin N. Rogers (33) that immature flowers may not develop properly following storage. The optimum stage would be when the cut flowers are at the youngest stage of full development. Marousky (27) stored chrysanthemum buds and opened flowers for up to 3 weeks. The opened flowers that were stored lasted 6 days longer than the flowers stored as buds. However, he found that storage in itself had no influence on the vase life of the chrysanthemum flowers. The length of period that chrysanthemum cut flowers have been recommended for dry storage at $31^{\circ}F$ was from 28-42 days (9, 32, 33).

Only the highest quality flowers should be used for dry storage (9, 32, 33). When cutting flowers for storage, one should work fast in

order to avoid wilting and keep respiration at a minimum. It is recommended to pack them directly without any hardening treatment (33). If the blossoms are wilted, they can be hardened for a few hours prior to packing (9, 32). However, any moisture on the stems and leaves from hardening tends to encourage disease organisms and the delay in storage from hardening could reduce the vase life of the flowers (33). After the flowers are taken from storage, they should be "hardened" before marketing (9, 32, 33). The stems should be recut, plunged into a hot (80-110$^{o}$F) preservative solution and stored 6 to 24 hours at a temperature around 50$^{o}$F.

# CHAPTER III

## METHODS AND MATERIALS

### General Methods and Materials

The chrysanthemum flowers that were used in the following experiments were produced in the horticulture greenhouses at Oklahoma State University. Four cultivars were used in the different experiments.[1] They were 'Yellow Shoesmith', 'Blaze', 'Shasta', and 'Indianapolis Pink'. Single stem plants were grown, and when cut, they were brought immediately to the laboratory.

In the various experiments the chrysanthemums were cut in 3 different stages of flower development according to bud diameter (Figure 3).

| | | Minimum | Maximum |
|---|---|---|---|
| Stage 1 | 'Yellow Shoesmith' | 23mm. | 35mm. |
| | 'Blaze' | 25mm. | 31mm. |
| | 'Shasta' | 13mm. | 16mm. |
| Stage 2 | 'Yellow Shoesmith' | 55mm. | 65mm. |
| | 'Blaze | 53mm. | 62mm. |
| | 'Shasta' | 25mm. | 45mm. |

Stage 3 'Yellow Shoesmith', 'Blaze' and "Indianapolis Pink' were grown as standards and were cut just before the center petals became fully expanded. 'Shasta' was grown as a spray type and was cut when the central flower was open and the other flowers well developed.

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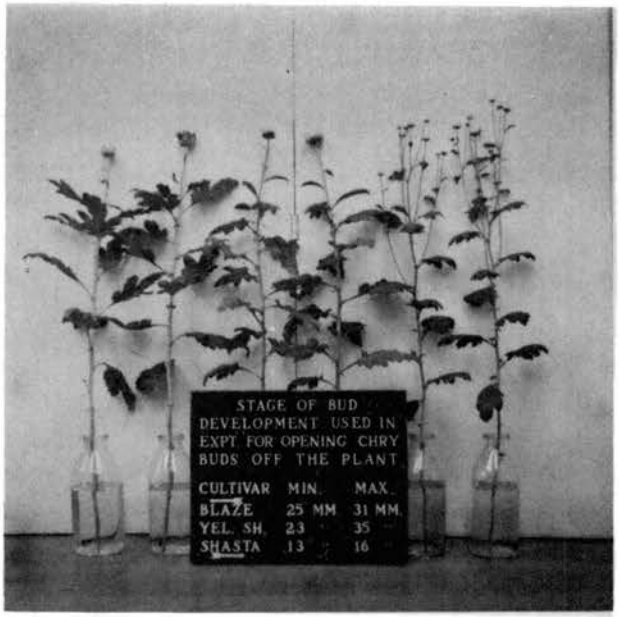
[1] Rooted cuttings, courtesy of Yoder Brothers, Inc., Barberton, Ohio.




Stage 1


Stage 2

Figure 3. Chrysanthemum Flower Buds in Stage One and Stage Two of Flower Development

The length of stem was thirty inches and the foliage was removed from the lower eight inches of stem. A slanting cut with a sharp knife was made at the stems basal end and four one-inch cuts were made up the sides of the stem. In all experiments in which chrysanthemum flower buds were utilized the stems were recut and put in fresh preservative solution when the flowers reached stage 3 of flower development. Only one flower was placed in each quart glass milk bottom. Everbloom was used as the standard floral preservative in all experiments excluding one and at the recommended concentration (28.35 grams/quart).[2] The light source used in both the growth chambers and in the laboratories was the Cool White flourescent lamp (F96T 12/CW/XHO) and were on continuously.

Total days cut was measured when the buds or flowers were brought to the opening chambers or laboratory rooms. Cut flower life was measured by subtracting days to open from total days cut. Decorative value was considered the criterion for ending cut flower life. Foliage was not used as a measure of cut flower life.

## Methods and Materials for Specific Experiments

### Light Intensity

Experiment I. 'Yellow Shoesmith', 'Blaze', and 'Shasta' chrysanthemum flower buds in stage one and stage two were opened under two light intensities in two different growth chambers (Figures 4 and 5).[3]

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[2]Everbloom, courtesy of Burpee Seed Co., Clinton, Iowa.

[3]A Sherer Controlled Environment Lab., Model Cel 37-14, Sherer-Gillett Co., Marshall, Michigan.

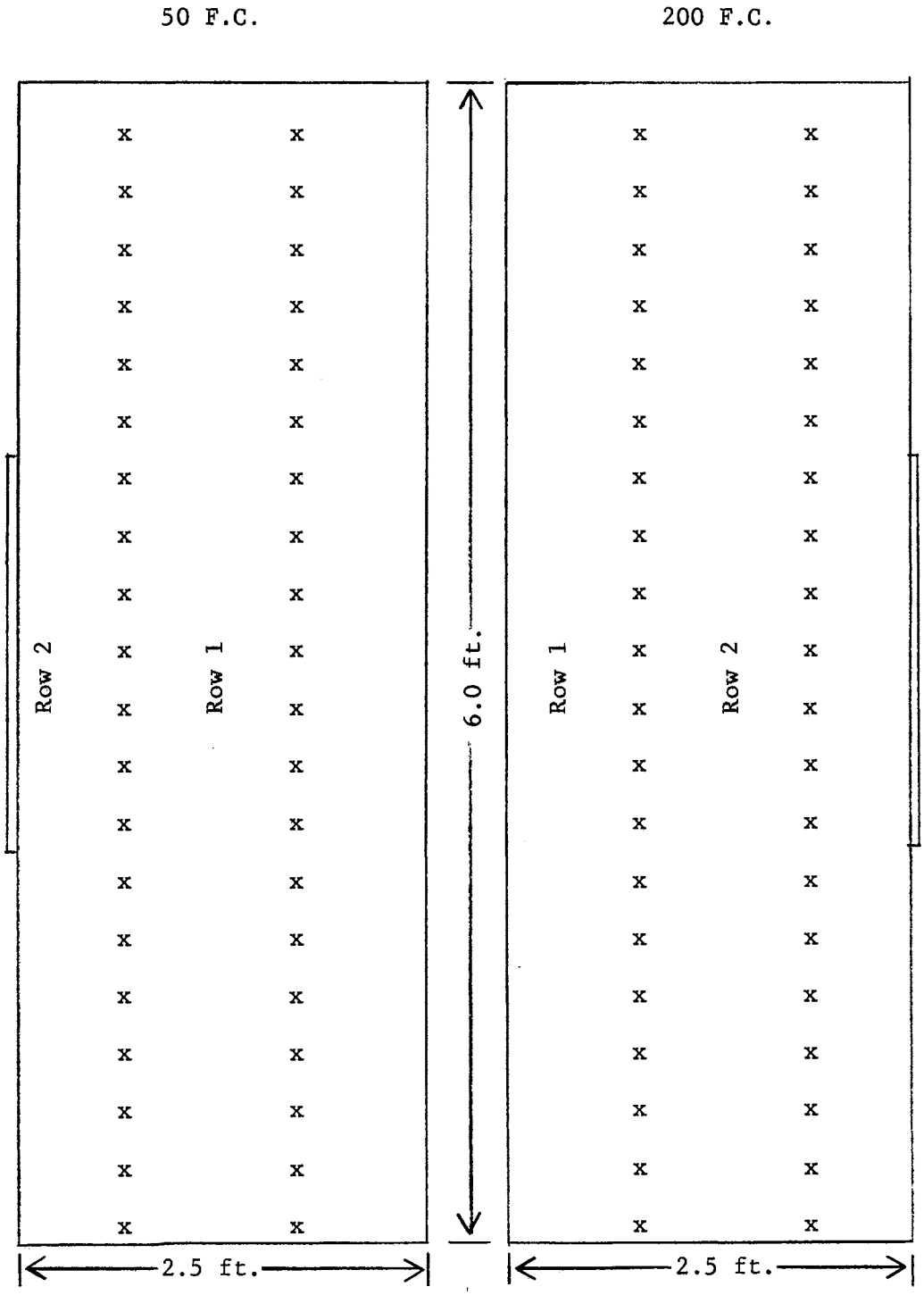


Figure 4. Layout of Growth Chambers

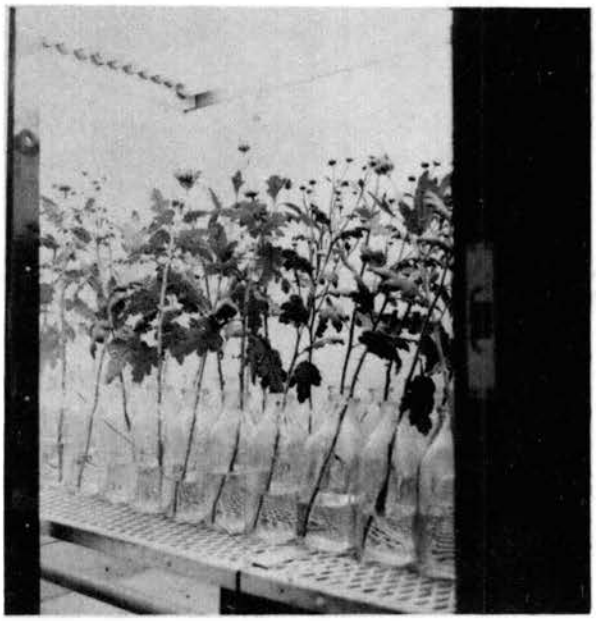

Figure 5. Chrysanthemum Flower Buds
in Growth Chamber

The light intensities were 50 and 200 foot-candles, the temperature 23.3 Centigrade, and the relative humidity 55-57 per cent. In each growth chamber, there were two rows with twenty quart glass milk bottles per row, with one flower in each bottle. Bottles one and twenty were for buffer flowers. There were three cultivars per row, with three flowers per cultivar in each of the two bud stages. In each row the flowers were assigned randomly. The layout for this experiment was a split split plot design. The main plots consisted of two light intensities (growth chambers) and each main plot had two rows and each sub-sub plot had a 3 by 2 factorial arrangement of cultivars and stages respectively. There were three flowers (milk bottles) within each of the six sub-sub plot treatments. Analysis for these types of experiments are given in Steel and Torrie (35).

Flowers which had been cut in stage one and two, and allowed to open in the growth chambers, were brought to a laboratory when open. Stage three flowers from the greenhouse were also placed in the laboratory at this time (Figures 6 and 7). The light intensity in the laboratory room was 120-150 foot-candles, the temperature 21.1-22.2 degrees centigrade, and the relative humidity 55-57 per cent. Rows one and three had flowers that were from the 50 foot-candle growth chamber. Milk bottles one and twenty-nine in each row were buffer flowers. Number two through ten milk bottles contained stage one flowers. Bottles eleven through nineteen contained stage two flowers. Bottles twenty through twenty-eight contained stage three flowers. The flowers were randomly assigned within the rows. Data on cut flower life (days) and flower diameter (millimeters) when opened, one week later, and two weeks later, were collected and analyzed statistically.

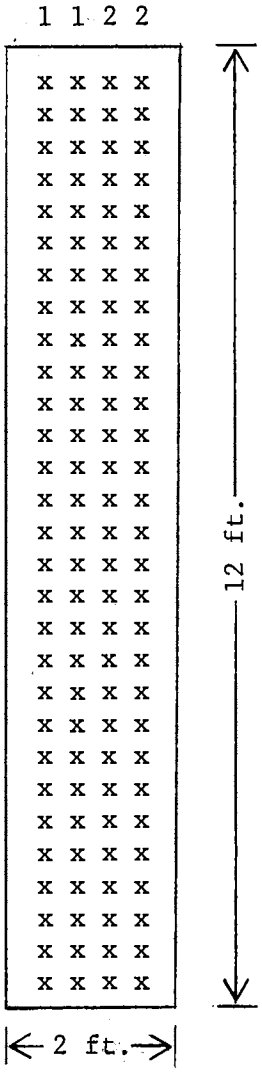


Figure 6. Layout for Light Intensity Experiment in the Laboratory

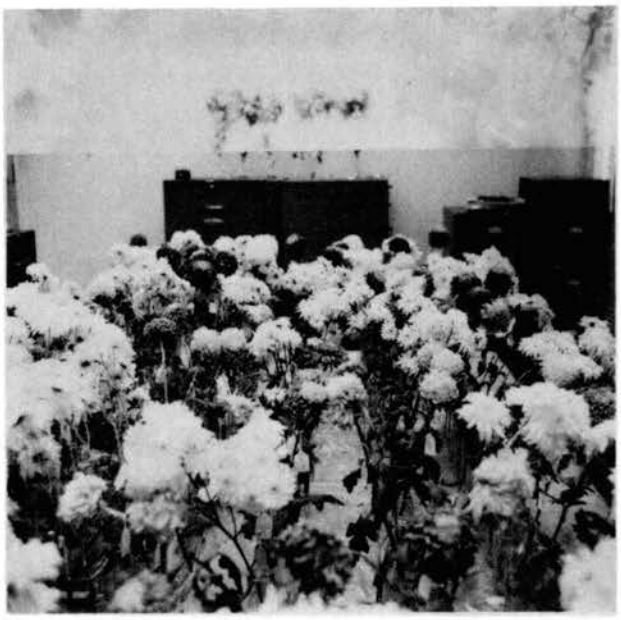

Figure 7. Chrysanthemum Flowers in Laboratory After Opened in Growth Chambers and Greenhouse

The data on the flower diameter added a sub-sub-sub plot (flower age) to the original design.

The first replication was started on October 26, 1969. On the 23rd of November, 1969, a second replication was started.

Experiment II. This experiment was conducted the same as experiment one except for the light intensities for opening the chrysanthemum flower buds in the growth chambers. The new light intensities were 200 and 400 foot-candles. Replication one was started on December 30, 1969. A second replication was started on January 27, 1970.

Experiment III. This experiment was conducted the same as the first two experiments except for improvised growth chambers and higher light intensities. The new light intensities were 400 and 600 foot-candles in the new growth chambers (Figure 8). The new growth chambers had aluminum foil in the sides and a fan to circulate the air (Figure 9), the temperature varied from 26.7 to 28.9 degrees centigrade and the relative humidity was 50 to 55 per cent. Figure 8 shows the way the rows were arranged. Bottles one, eleven, twelve, and twenty-two were buffer flowers. The laboratory for testing cut flower life and flower diameter was the same as for the first two experiments. The data were collected and analyzed in exactly the same manner as in the first experiment.

Replication one was started on March 3, 1970 and replication two was started April 4, 1970.

Experiment IV. This experiment was conducted the same as experiment three except for the light intensities for opening the chrysanthemum flower buds in the growth chambers. The new light intensities were 600 and 800 foot-candles. Replication one was started on March 3, 1970 and a second replication was started on April 4, 1970.

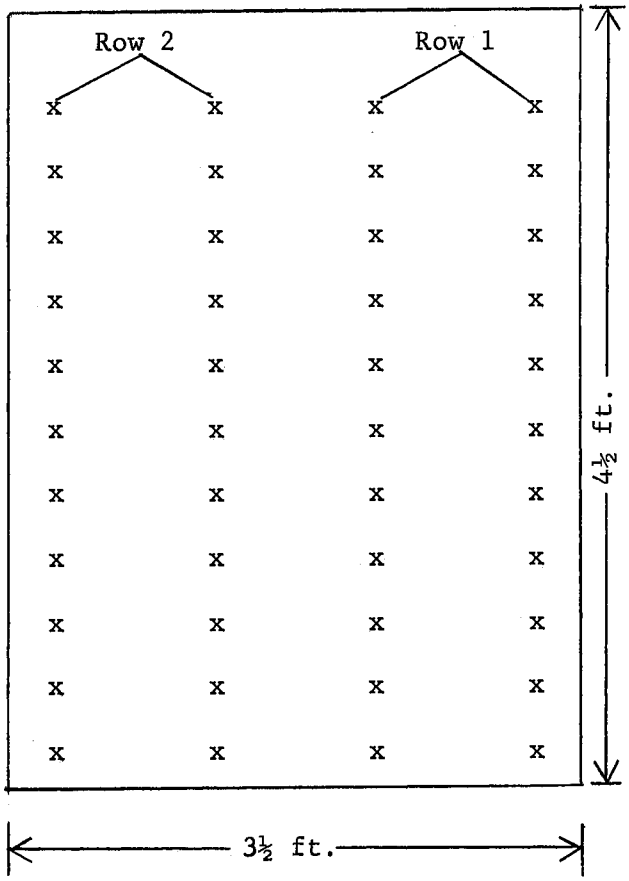


Figure 8. Layout for Improvised Growth Chambers

Figure 9. Chrysanthemum Flower Buds in Improvised Growth Chamber

Bud Cut vs. On the Plant Opening Under Similar Conditions

Experiment V. Buds in stage one flower development were selected January 30, 1970 from the cultivars 'Yellow Shoesmith', 'Blaze', and 'Shasta'. One-half of the flower buds of each cultivar were cut and placed in opening solution (recommended concentration of Everbloom), while the others were left intact on the plant. The flower buds that were cut were left in the greenhouse to open.

When the flower buds opened in the greenhouse the flowers were brought to a laboratory and cut flower life and flower diameter when opened, one week later, and two weeks later, was measured. The light intensity in the laboratory room was 120-150 foot-candles, the temperature 22.2-23.3 degrees centigrade and the relative humidity 50-55 per cent. There were four rows with twenty flowers per row. Bottles one and twenty contained buffer flowers. In each row there were nine flowers that were opened on the plant and nine flowers that were opened off the plant. A second replication of this experiment was started on February 25, 1970.

Stem Cutting

Experiment VI. A test was initiated December 27, 1969 comparing seven different ways of cutting the stems of chrysanthemum flowers. The flowers were in stage three when brought to the laboratory. The light intensity in the laboratory room was 60-70 foot-candles, the temperature 22.2-23.3 degrees centigrade and the relative humidity 50-55 per cent. The floral preservative Petalife was used in the first replication, while Everbloom was used in the second replication.

'Indianapolis Pink' was the only variety that was used in the experiments for stem cuttings.

The seven ways of cutting the stems of the chrysanthemum flower were: (1) slant cut with stem crushed one inch; (2) slant cut with stem tip crushed; (3) snapping the stem; (4) slant cut; (5) horizontal cut; (6) slant cut with four one-inch cuts up the side; and (7) stem cut with shears. The stems were eighteen inches long and all cuts were in the succulent part of the stem.

In the laboratory there were four rows with twenty-three flowers per row. Bottles one and twenty-three contained buffer flowers. All seven treatments were in each row with three flowers per treatment. The flowers were randomly assigned. Data were collected on cut flower life in order to compare the effects of the seven ways of cutting the stems. A second replication was started on January 28, 1970.

Experiment VII. This experiment was conducted the same as experiment six except row one and row three cut flowers were cut in the succulent part of the stem and row two and row four cut flowers were cut in the woody part of the stem (Figure 10). All seven treatments were in each row. Data on cut flower life were used to compare the seven ways of cutting the stem in the woody area and in the succulent part of the stem. The data were also used to compare woody cuts vs. cuts in the more succulent part of the stem. The first replication was started March 5, 1970. Replication two was started April 8, 1970.

## Flower Bud Opening Solutions

Experiment VIII. 'Yellow Shoesmith', 'Blaze', and 'Shasta' were used in testing effect of different opening solutions for chrysanthemum

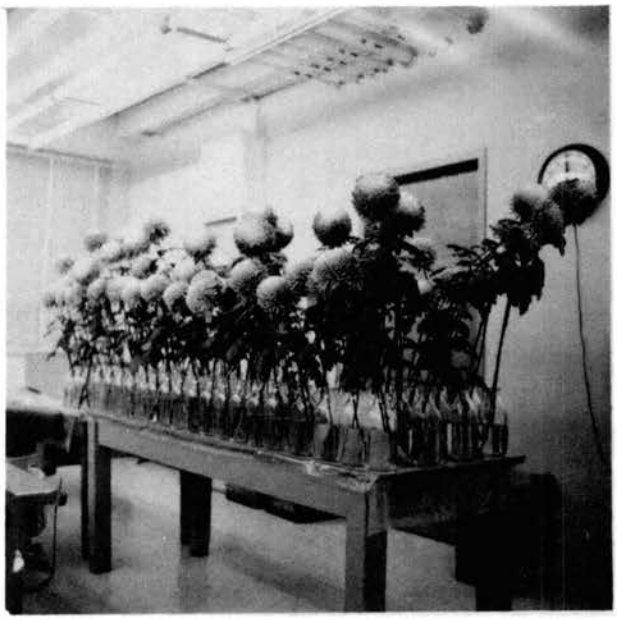

Figure 10. Laboratory Layout for Stem Cutting Experiment

flower buds. On October 27, 1969, stage one flower buds were brought to the laboratory. In the laboratory the light intensity was 120-150 foot-candles, the temperature 22.3-23.3 degrees centigrade, and the relative humidity 50-55 per cent. There were four rows in the laboratory with seventeen flowers in milk bottles per row. Bottles one and seventeen contained buffer flowers. Five different opening solutions were used in this experiment. They were: (1) Everbloom at 28.35 grams /quart, (2) 200 parts per million 8-hydroxyquinoline citrate plus 2% sucrose, (3) Petalife at 15.20 grams/quart, (4) F. M. Budmagic at 7.09 grams/quart,[4] and (5) tap water. All five opening solutions and the three cultivars were in each row. The flowers were assigned randomly in the rows. After the flower buds opened, the stems were recut and placed in distilled water. This was done in order to test the different opening solutions and not floral preservative effects. Data on the number of days for the flowers to open and cut flower life were collected and compared. On November 23, 1969 a second replication was started.

## Floral Preservative Effects

Experiment IX. Flowers of 'Yellow Shoesmith', 'Blaze', 'Indianapolis Pink', and 'Shasta' in stage three flower development were brought from the greenhouse and placed in the laboratory. In the laboratory the light intensity was 60-70 foot-candles, the temperature 22.2-23.3 degrees centigrade, and the relative humidity 50-55 per cent. There were twenty treatments per row and four rows in the experiment with twenty-two milk bottles each. Bottles one and twenty-two contained

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[4]F. M. Budmagic, F. M. Regular, F. M. Super, courtesy of Arkmost Research, Inc., Tulsa, Oklahoma.

buffer flowers. Each row consisted of a different cultivar.

The following preservatives were used at one-half the recommended rate, the recommended rate, and twice the recommended rate: Everbloom, F. M. Budmagic, F. M. Regular, F M. Super, and Petalife. The recommended rates of the preservatives were: (a) Everbloom at 28.35 grams/quart; (b) F. M. Budmagic at 7.09 grams/quart; (c) F. M. Regular at 7.09 grams/quart; (d) F. M. Super at 28.35 grams/quart; and (e) Petalife at 15.20 grams/quart. The other treatments were water, 2% sucrose plus 200 ppm 8-HQC, 4% sucrose plus 100 ppm 8-HQC plus 200 ppm Alar, 4% sucrose plus 200 ppm 8-HQC plus 300 ppm Alar, and 4% sucrose plus 400 ppm 8-HQC plus 500 ppm Alar.

The flowers were assigned randomly. Data were collected on cut flower life, flower diameter size at one and two weeks, and the pH of the solution at the start of the test, three weeks later, and six weeks later.

The first replication was started on March 3, 1970. On the 6th of May, 1970, a second replication was started.

## Long-Term Storage of Flower Buds

Experiment X. On January 29, 1970 chrysanthemum flower buds (stage one) of the cultivars 'Blaze' and 'Shasta' were stored one, two, three, and four weeks under different treatments. The treatments were: (1) stored dry at -0.56 degrees centigrade in two mil polyethylene plastic film that was folded and stapled every six inches; (2) stored with end of stems in oasis at -0.56 degrees centigrade in two mil polyethylene plastic film that was folded and stapled every six inches; (3) stored at 4.44 degrees centigrade in quart glass milk

bottles filled with Everbloom at 28.35 grams/quart; and (4) stored at 4.44 degrees centigrade in wet newspaper wrapped around the base of the stems and placed in two mil polyethylene film that was folded and stapled every six inches (Figure 11). Flowers were stored in bunches of three.

After storage the stems were recut and brought to the laboratory (Figure 12). Six flowers of each treatment (24 total) were brought out from storage each week. In each row there were fourteen flowers with flowers in bottles one and fourteen as buffer flowers. The flowers were assigned randomly. The light intensity in the laboratory was 120-150 foot-candles, the temperature 22.2-23.3 degrees centigrade, and the relative humidity was 50-55 per cent. Data were collected on number of days to open, cut flower life, and flower diameter size when open. A second replication was started May 1, 1970.

Figure 11. The Different Treatments Used for Long-Term Storage of Flower Buds

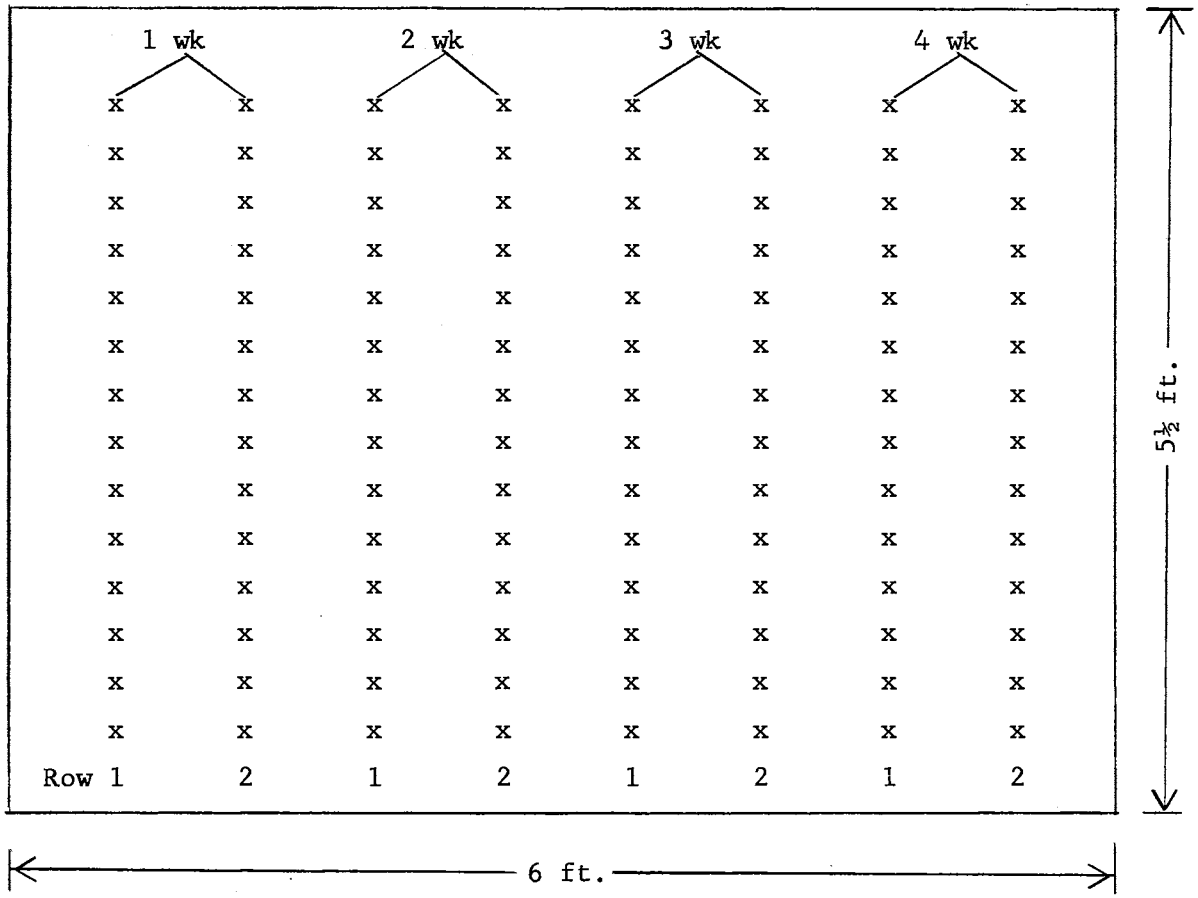
Treatments from Left to Right:

(1) Blaze and Shasta Stored at 4.44 Degrees Centigrade in Quart Glass Milk Bottles Filled with Everbloom.

(2) Blaze and Shasta Stored at 4.44 Degrees Centigrade in Wet Newspaper Wrapped Around the Base of the Stems and Placed in Two Mil Polyethylene Film that Was Folded and Stapled Every Six Inches.

(3) Blaze and Shasta Stored with End of Stems in Oasis at -0.56 Degrees Centigrade in Two Mil Polyethylene Plastic Film that Was Folded and Stapled Every Six Inches.

(4) Blaze and Shasta Stored Dry at -0.56 Degrees Centigrade in Two Mil Polyethylene Plastic Film that Was Folded and Stapled Every Six Inches.




Row 1 = all storage at -0.56 degrees centigrade
Row 2 = all storage at 4.44 degrees centigrade.

Figure 12. Layout for Long-term Storage Experiment in the Laboratory

# CHAPTER IV

## RESULTS

### Experiment I

In this experiment chrysanthemum flowers of the three cultivars cut in stages one and two were opened under light intensities of 50 and 200 foot-candles. The over-all average number of days to open for buds cut in stage one was 11.10 and for stage two, 4.08 days. These and other bud opening data for each cultivar, stage of flower bud development at cutting and light intensity are given in Table I. The over-all average for each light intensity showed that the higher light intensity (200 F.C.) caused the flowers to open slightly faster than those in the lower light intensity (50 F.C.). Flowers of the cultivar 'Shasta' opened slightly faster than did those of 'Blaze' and 'Yellow Shoesmith'.

Data on cut flower life of the three cultivars, two stages of flower bud development at cutting, and light intensity are shown in Table II. Stage one had a mean cut flower life of 22.86 days at 50 foot-candles and 24.33 days at 200 foot-candles. Stage two had a mean cut flower life of 27.89 days at 50 foot-candles and 27.69 days at 200 foot-candles. Flowers that were opened under the higher light intensity had a cut flower life of 26.01 days while flowers that opened under the lower light intensity had a cut flower life of 25.38 days. Flowers from the lower light intensity had a 2.42% decrease in cut flower life.

TABLE I

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE AVERAGE NUMBER OF DAYS REQUIRED FOR FLOWER OPENING OF CHRYSANTHEMUMS, EXPERIMENT I

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 50 F.C. | 12.58 | 11.00 | 10.75 | 11.44 | 4.92 | 4.92 | 2.91 | 4.25 |
| 200 F.C. | 11.42 | 11.00 | 9.83 | 10.75 | 4.83 | 4.83 | 2.08 | 3.92 |
| Average | 12.00 | 11.00 | 10.29 | 11.10 | 4.88 | 4.88 | 2.50 | 4.08 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

* See page 18 for explanation of stages of flower bud development.

TABLE II

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE CUT FLOWER LIFE IN DAYS OF CHRYSANTHEMUMS, EXPERIMENT I

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 50 F.C. | 22.25 | 21.58 | 24.75 | 22.86 | 29.33 | 25.58 | 28.75 | 27.89 |
| 200 F.C. | 23.92 | 21.92 | 27.17 | 24.33 | 28.33 | 26.33 | 28.42 | 27.69 |
| Average | 23.08 | 21.75 | 25.96 | 23.60 | 28.83 | 25.96 | 28.58 | 27.80 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

A statistical analysis of experiment one for days to open and cut flower life is shown in Table III. The analysis showed that light intensity had no significant effect on days to open and cut flower life. The degrees of freedom to make the F-test were only one and to have a significant effect the differences between the two light intensities would have to be extremely large. Bud stage at cutting and cultivar were significant at the 1% level both for days to open and cut flower life. Row was significant at the 5% level for cut flower life. The mean cut flower life for row one was 25.11 days and for row two, 26.28 days.

Figure 13 shows the effect of trial on cut flower life for the three cultivars when flowers were cut in stage three of flower development. Flowers of the cultivar 'Yellow Shoesmith' had a mean cut flower life in Trial 1 of 37.67 days and in Trial 2, only 21.42 days (over-all mean for both trials was 29.54 days). Flowers of the cultivar 'Blaze' had a mean cut flower life in Trial 1 of 29.00 days and a very similar cut flower life in Trial 2 of 29.33 days (over-all mean for both trials was 29.17 days). Flowers of the cultivar 'Shasta' had a mean cut flower life in Trial 1 of 36.50 days and only 26.42 days in Trial 2 (over-all mean for both trials was 31.46 days). The mean flower life for all cultivars in trial one was 34.39 days and 25.72 days for trial two. Table IV shows the statistical analysis for the cut flower life discussed above for the flowers opened on the plant (stage three). Trial, cultivar and the two factor interaction of trial by cultivar were all significant at the 1% level.

TABLE III

ANALYSIS OF VARIANCE FOR DAYS TO OPEN AND FOR CUT FLOWER LIFE, EXPERIMENT I

| Source of Variation | df | Days To Open MS | Cut Flower Life MS |
|---|---|---|---|
| Total | 143 | | |
| Trial (T) | 1 | 25.84 | 1,213.36 |
| Foot Candles (L) | 1 | 9.51 | 14.69 |
| Error (a) TL | 1 | 1.17 | 16.00 |
| Row (R) | 1 | 1.17 | 49.00* |
| R x L | 1 | 4.34 | 1.36 |
| Error (b) TR x TRL | 2 | 1.03 | .51 |
| Stage (S) | 1 | 1,771.01** | 633.36** |
| Cultivar (CV) | 2 | 54.36** | 142.59** |
| S x CV | 2 | 8.44 | 29.30 |
| S x L | 1 | 1.17 | 25.00 |
| CV x L | 2 | 2.19 | 1.59 |
| S x CV x L | 2 | 1.19 | 9.77 |
| Error (c) TS + TCV + TSCV + TSL + TCVL + TSCVL + RS + RCV + RSCV + RSL + RCVL + RSCVL + TRS + TRCV + TRSCV + TRSL + TRCVL + TRSCVL | 30 | 3.05 | 11.63 |
| Flowers in CV in R | 96 | 4.84 | 4.22 |
| Over-all Mean | | 7.59 | 25.69 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

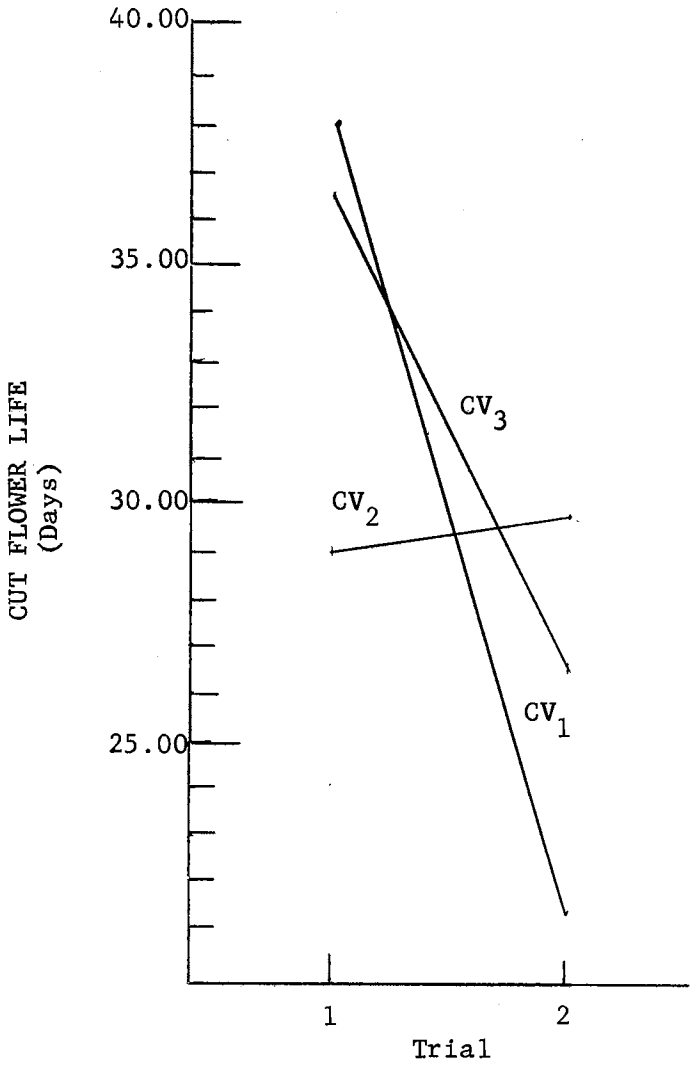



Figure 13. The Effect of Trial by Cultivar Interaction on Cut Flower Life of Flowers Cut in Stage Three* of Flower Development, Experiment I

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stage three flower development.

TABLE IV

ANALYSIS OF VARIANCE FOR CUT FLOWER LIFE FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT I

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 71 | |
| Trials (T) | 1 | 1,352.00** |
| Rows in Lab (R) | 3 | 3.00 |
| Error (a) TR | 3 | 11.59 |
| Cultivar (CV) | 2 | 36.26** |
| CV x T | 2 | 421.54** |
| Error (b) RCV + TRCV | 12 | 4.59 |
| Flowers in CV in R | 48 | 3.86 |
| Over-All Mean | | 30.06 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

Cut flower life data for flowers from the three flower development stages were not compared statistically. The cut flower life, however, for flowers cut in stages one, two, and three for the three cultivars is shown in Table V. In every case, flowers cut in stage three lasted longer than flowers cut in stage two, and stage two flowers lasted longer than flowers cut in stage one. For all cultivars, stage one flowers had a mean cut flower life of 23.59 days; those cut in stage two had a mean cut flower life of 27.79 days; and those cut in stage three had a mean cut flower life of 30.06 days. Since chrysanthemums are normally cut at stage three flower development, cutting at stage two caused a 7.55% decrease, while cutting at stage one caused a 21.52% decrease in cut flower life.

Measurements were made of flower diameter; when the flowers opened (stage three), one week later, and two weeks later. In the analysis of variance (Table VIII), this was termed age. The data showed that there was a slight increase in diameter as the light intensity increased. The mean flower diameter of stage one flowers was 99.12 millimeters at 50 foot-candles and 104.91 millimeters at 200 foot-candles. For stage two the mean flower diameter was 111.94 millimeters at 50 foot-candles and 114.95 millimeters at 200 foot-candles. Table VI shows the mean flower diameter for all three cultivars and stages. The cultivar 'Yellow Shoesmith' had the largest flower diameter for all three stages and 'Shasta', a spray-type cultivar, had the smallest flower diameter for all three stages. The mean flower diameter when the flowers opened (stage 3), one week after the flowers opened, and two weeks after the flowers opened is shown in Table VII. The flowers increased in flower diameter during the first week after they were considered opened (stage 3) and decreased in flower diameter the second week.

TABLE V

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE MEAN NUMBER OF DAYS FOR CUT FLOWER LIFE OF CHRYSANTHEMUM FLOWERS, EXPERIMENT I

| Cultivar | Mean Number of Days for Cut Flower Life | | |
|---|---|---|---|
| | Stage 1* | Stage 2* | Stage 3* |
| 'Yellow Shoesmith' | 23.08 | 28.83 | 29.54 |
| 'Blaze' | 21.75 | 25.96 | 29.17 |
| 'Shasta' | 25.96 | 28.58 | 31.46 |
| Over-all Average | 23.59 | 27.79 | 30.06 |

*See page 18 for explanation of stages of flower development.

TABLE VI

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE OVER-ALL MEAN* OF FLOWER DIAMETER IN MILLIMETERS, EXPERIMENT I

| Cultivar | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 'Yellow Shoesmith' | 117.15 | 131.74 | 151.56 |
| 'Blaze' | 111.88 | 122.01 | 132.92 |
| 'Shasta' | 77.01 | 86.60 | 96.77 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE VII

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND AGE ON THE OVER-ALL MEAN FLOWER DIAMETER IN MILLIMETERS FOR THE THREE CHRYSANTHEMUM CULTIVARS, EXPERIMENT I

| Age* | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 1 | 103.47 | 111.25 | |
| 2 | 104.30 | 118.54 | 129.31 |
| 3 | 98.26 | 110.56 | 124.86 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

Table VIII shows the analysis of variance pertaining to flower diameter of flower buds cut in stage one and stage two. Stage three flowers were also analyzed for flower diameter as shown in Table IX. The analysis showed that light intensity during opening of the buds had no significant effect on the three measurements for flower diameter. Again, the degrees of freedom were only one to make the F-test, and to have a significant effect the differences between the two light intensities would have to be extremely large. A main effect of cultivar was present at the 1% level for stages one and two and at the 5% level for stage three. The three stages also showed a main effect of age on flower diameter at the 1% level. A two factor interaction of age by trial for flower diameter was significant at the 1% level for all three stages. Another two factor interaction that was significant at the 1% level for all three stages was the age by cultivar interaction. Stage one flowers had a row by trial interaction which was significant at the 5% level. Stage one also had a three factor interaction of row by cultivar by foot-candles of light. Stage two had a three factor interaction of age by trial by cultivar. Stage three had a three factor interaction of age by cultivar by row.

All three stages were not compared statistically for flower diameter. Flowers cut in stage one, however, had a mean flower diameter of 102.01 millimeters. Those cut in stage two had a mean flower diameter of 113.45 millimeters and stage three flowers had a mean flower diameter of 127.08 millimeters. Since chrysanthemums are normally cut at stage three, cutting earlier at stage two caused a 10.73% decrease in flower diameter and cutting at stage one caused a 19.73% decrease in flower diameter.

TABLE VIII

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER, EXPERIMENT I

| Source of Variation | df | Stage 1 MS | Stage 2 MS |
|---|---|---|---|
| Total | 215 | | |
| Trial (T) | 1 | 1,584.37 | 651.04 |
| Foot-candles (L) | 1 | 1,808.45 | 489.00 |
| Error (a) TL | 1 | 26.04 | 5.67 |
| Cultivar (CV) | 2 | 34,251.39** | 40,636.57** |
| CV x L | 2 | 128.24 | 17.13 |
| Error (b) TCV + TCVL | 4 | 629.17 | 987.04 |
| Age (A) | 2 | 771.87** | 1,409.14** |
| A x T | 2 | 552.43** | 644.79 |
| A x L | 2 | 14.70 | .81 |
| A x T x L | 2 | 54.51 | 3.59 |
| A x CV | 4 | 249.83** | 388.66** |
| A x T x CV | 4 | 26.91 | 509.72** |
| A x CV x L | 4 | 32.93 | 22.69 |
| A x T x CV x L | 4 | 12.33 | 8.10 |
| Error (c) A by F within CV, L R, T, combinations | 96 | 25.81 | 30.84 |
| Row (R) | 1 | 14.00 | 26.04 |
| R x T | 1 | 376.04* | .16 |
| R x CV | 2 | 103.24 | 18.06 |
| R x L | 1 | 176.04 | 1.04 |
| R x CV x T | 2 | 37.50 | 111.57 |
| R x CV x L | 2 | 268.06* | 18.06 |
| R x L x T | 1 | 214.00 | 97.34 |
| R x CV x L X T | 2 | 150.46 | 72.69 |
| A x R | 2 | 41.78 | 23.26 |
| A x R x T | 2 | 27.43 | 27.89 |
| A x R x CV | 4 | 36.75 | 34.03 |
| A x R x L | 2 | 21.18 | 10.76 |
| A x R x CV x T | 4 | 23.78 | 26.85 |
| A x R x CV x L | 4 | 12.67 | 50.69 |
| A x R x L x T | 2 | 2.20 | 8.45 |
| A x R x CV x L x T | 4 | 46.47 | 8.80 |
| Flowers in CV in R | 48 | 61.23 | 53.59 |
| Over-all Mean | | 102.01 | 113.45 |

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

TABLE IX

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT I

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 143 | |
| Trials (T) | 1 | 5,256.25 |
| Cultivar (CV) | 2 | 37,250.52* |
| Error (a) | 2 | 1,769.27 |
| CVT | | |
| Age (A) | 1 | 711.11** |
| A x CV | 2 | 574.13** |
| A x R | 3 | 16.20 |
| A x CV x R | 6 | 6.31 |
| A x T | 1 | 1,284.03** |
| A x R x T | 3 | 3.01 |
| A x CV x T | 2 | 15.80 |
| A x R x CV x T | 6 | 14.64 |
| Error (b) | 48 | 28.47 |
| A by F within CV, R, T, combinations | | |
| Row (R) | 3 | 7.87 |
| R x U | 6 | 29.92 |
| R x T | 3 | 25.23 |
| R x U x T | 6 | 15.34 |
| Flowers in CV and R | 48 | 42.36 |
| Over-all Mean | | 127.08 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

## Experiment II

In this experiment chrysanthemum flowers of the three cultivars cut in stages one and two were opened under light intensities of 200 and 400 foot-candles. The over-all average number of days to open for buds cut in stage one was 10.69 and for stage two, 5.97 days. These and other bud opening data for each cultivar, stage of flower bud development at cutting, and light intensity are given in Table X. The over-all average for each light intensity showed that the higher light intensity (400 F.C.) caused the flowers to open slightly faster than those in the lower light intensity (200 F.C.). Flowers of the cultivar 'Shasta' opened slightly faster than did those of 'Blaze' and 'Yellow Shoesmith'.

Data on cut flower life of the three cultivars, two stages of flower bud development at cutting, and light intensity are shown in Table XI. Stage one had a mean cut flower life of 18.47 days at 200 foot-candles and 20.64 days at 400 foot-candles. Stage two had a mean cut flower life of 21.69 days at 200 foot-candles and 23.33 days at 400 foot-candles. Flowers that were opened under the higher light intensity had a cut flower life of 26.28 days, while flowers that opened under the lower light intensity had a cut flower life of 25.11 days. Flowers from the lower light intensity had a 4.45% decrease in cut flower life.

A statistical analysis of experiment two for days to open and cut flower life is shown in Table XII. The analysis showed that light intensity had no significant effect on days to open and cut flower life. Bud stage at cutting and cultivar were significant at the 1% level both for days to open and cut flower life.

TABLE X

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE AVERAGE NUMBER OF DAYS REQUIRED FOR FLOWER OPENING OF CHRYSANTHEMUMS, EXPERIMENT II

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 200 F.C. | 11.58 | 10.83 | 10.50 | 10.97 | 6.25 | 6.58 | 5.33 | 6.06 |
| 400 F.C. | 10.83 | 11.16 | 9.25 | 10.42 | 6.08 | 6.58 | 5.00 | 5.89 |
| Average | 11.21 | 11.00 | 9.88 | 10.69 | 6.17 | 6.58 | 5.17 | 5.97 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta

*See page 18 for explanation of stages of flower bud development.

TABLE XI

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE CUT FLOWER LIFE IN DAYS OF CHRYSANTHEMUMS, EXPERIMENT II

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 200 F.C. | 18.50 | 17.08 | 19.83 | 18.47 | 21.17 | 19.67 | 24.25 | 21.69 |
| 400 F.C. | 20.58 | 18.67 | 22.67 | 20.64 | 22.50 | 21.50 | 26.00 | 23.33 |
| Average | 19.54 | 17.88 | 21.25 | 19.56 | 21.83 | 20.58 | 25.13 | 22.51 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

TABLE XII

ANALYSIS OF VARIANCE FOR DAYS TO OPEN AND FOR CUT FLOWER LIFE, EXPERIMENT II

| Source of Variation | df | Days To Open MS | Cut Flower Life MS |
|---|---|---|---|
| Total | 143 | | |
| Trial (T) | 1 | 0.25 | 1,242.56 |
| Foot Candles (L) | 1 | 4.69 | 130.34 |
| Error (a) TL | 1 | 0.11 | 39.06 |
| Row (R) | 1 | 6.25 | 14.06 |
| R x L | 1 | 7.11 | 1.17 |
| Error (b) TR x TRL | 2 | 1.57 | 10.67 |
| Stage (S) | 1 | 802.78** | 315.00** |
| Cultivar (CV) | 2 | 23.90** | 192.36** |
| S x CV | 2 | 1.17 | 8.08 |
| S x L | 1 | 1.36 | 2.51 |
| CV x L | 2 | 2.84 | 1.36 |
| S x CV x L | 2 | 1.26 | 1.44 |
| Error (c) TS + TCV + TSCV + TSL + TCVL + TSCVL + RS + RCV + RSCV + RSL + RCVL + RSCVL + TRS + TRCV + TRSCV + TRSL + TRCVL + TRSCVL | 30 | 2.64 | 22.87 |
| Flowers in CV in R | 96 | 1.15 | 3.02 |
| Over-all Mean | | 8.33 | 21.03 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

Figure 14 shows the effect of trial one cut flower life for the three cultivars when flowers were cut in stage three of flower development. Flowers of the cultivar 'Yellow Shoesmith' had a mean cut flower life in trial one of only 27.08 days and in trial two, 33.42 days (over-all mean for both trials was 30.25 days), whereas those of the cultivar 'Blaze' had a mean cut flower life in trial one of only 24.42 days and in trial two, 35.25 days (over-all mean for both trials was 29.83 days). Flowers of the cultivar 'Shasta' had a mean cut flower life in trial one of 29.16 days and a very similar cut flower life in trial two of 30.50 days (over-all mean for both trials was 29.83 days). The mean cut flower life for all cultivars in trial one was 26.89 days and 33.06 days for trial two. Table XIII shows the statistical analysis for the cut flower life discussed above for the flowers opened on the plant (stage three). Trial and the two factor interaction of trial by cultivar was significant at the 1% level.

Cut flower life data for flowers from the three flower development stages were not compared statistically. The cut flower life, however, for flowers cut in stages one, two, and three for the three cultivars is shown in Table XIV. In every case, flowers cut in stage three lasted longer than flowers cut in stage two, and stage two cut flowers lasted longer than flowers cut in stage one. Over all cultivars, stage one flowers had a mean cut flower life of 19.56 days; those cut in stage two had a mean cut flower life of 22.51 days; and those cut in stage three had a mean cut flower life of 29.97 days. Since chrysanthemums are normally cut at stage three flower development, cutting earlier at stage two caused a 24.89% decrease in cut flower life and cutting at stage one caused a 34.73% decrease in cut flower life.

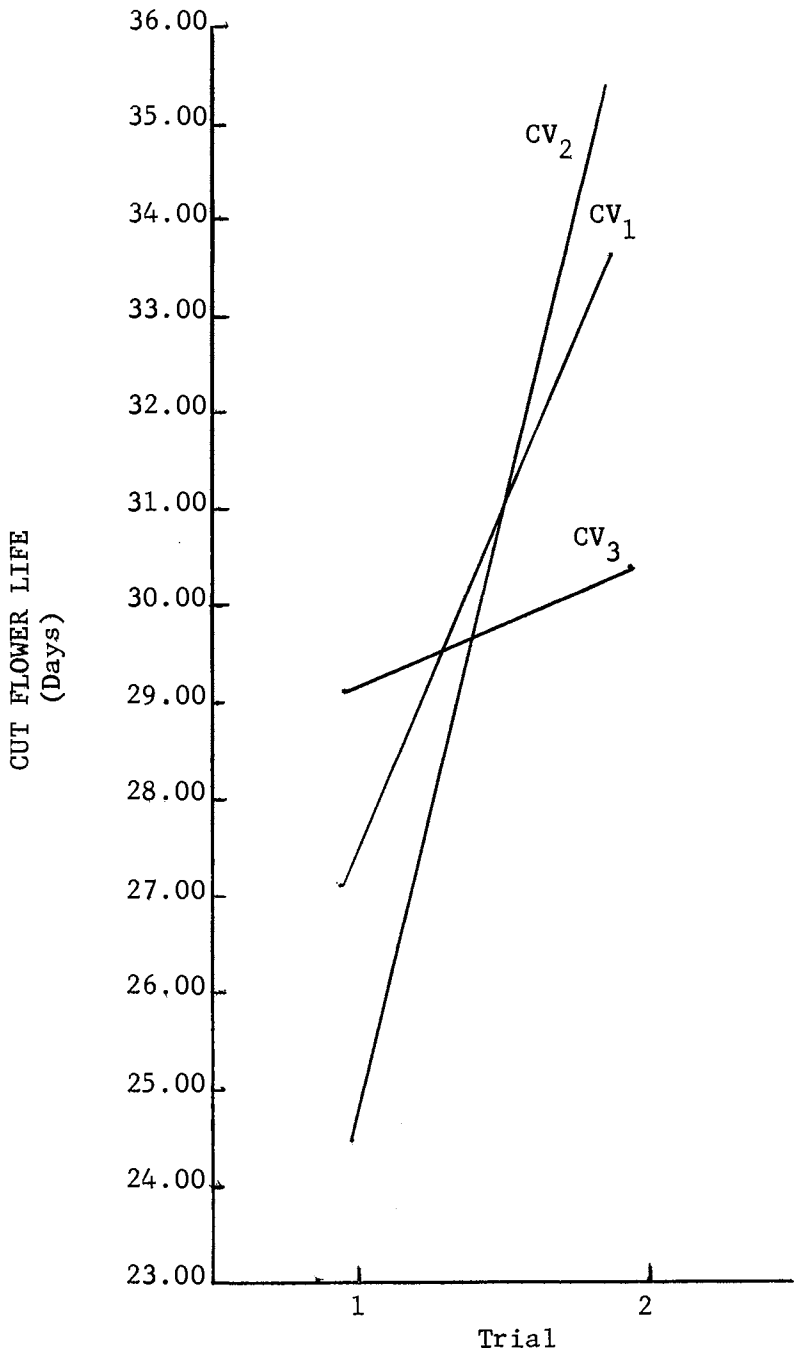



Figure 14. The Effect of Trial by Cultivar Interaction on Cut Flower Life of Flowers Cut in Stage Three* of Flower Development, Experiment II

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stage three flower development.

TABLE XIII

ANALYSIS OF VARIANCE FOR CUT FLOWER LIFE FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT II

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 71 | |
| Trials (T) | 1 | 684.50** |
| Rows in Lab (R) | 3 | 1.87 |
| Error (a) | 3 | 2.83 |
| TR | | |
| Cultivar (CV) | 2 | 1.39 |
| CV x T | 2 | 135.50** |
| Error (b) | 12 | 2.07 |
| RCV + TRCV | | |
| Flowers in CV in R | 48 | 2.31 |
| Over-all Mean | | 29.97 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

TABLE XIV

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE MEAN NUMBER OF DAYS FOR CUT FLOWER LIFE OF CHRYSANTHEMUM FLOWERS, EXPERIMENT II

| Cultivar | Mean Number of Days for Cut Flower Life | | |
|---|---|---|---|
| | Stage 1* | Stage 2* | Stage 3* |
| 'Yellow Shoesmith' | 19.54 | 21.83 | 30.25 |
| 'Blaze' | 17.88 | 20.58 | 29.83 |
| 'Shasta' | 21.25 | 25.13 | 29.83 |
| Over-all Average | 19.56 | 22.51 | 29.97 |

*See page 18 for explanation of stages of flower development.

The measurements that were made of flower diameter showed that there was a slight decrease in flower diameter with the higher light intensity. The mean flower diameter of stage one flowers at 200 foot-candles was 107.73 millimeters and at 400 foot-candles, 106.06 millimeters. For stage two the mean flower diameter was 117.55 millimeters at 200 foot-candles and 116.75 millimeters at 400 foot-candles. Table XV shows the mean flower diameter for all three cultivars and stages. Flowers of the cultivar 'Yellow Shoesmith' had flowers of the largest diameter for all three stages and 'Shasta' had the smallest flower diameter for all three stages. The mean flower diameter when the flowers opened (stage three), one week after the flowers opened, and two weeks after the flowers opened is shown in Table XVI. This table shows that for stages one and two the flower diameter decreased from the time the flowers were considered open. Stage three flowers increased in flower diameter during the first week after they were considered open (stage three) and decreased in flower diameter the second week.

Table XVII shows the analysis of variance pertaining to flower diameter for flowers cut in stage one and stage two. Stage three flowers were also analyzed for flower diameter in Table XVIII. The analysis showed that light intensity during opening of the buds had no significant effect on the three measurements for flower diameter. A main effect of cultivar was present at the 1% level for stage two and at the 5% level for stages one and three. The three stages also showed a main effect of age on flower diameter at the 1% level. A two factor interaction of age by cultivar for flower diameter was significant at the 1% level for all three stages. Age by trial was significant for

TABLE XV

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE OVER-ALL MEAN* OF FLOWER DIAMETER IN MILLIMETERS, EXPERIMENT II

| Cultivar | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 'Yellow Shoesmith' | 117.92 | 130.42 | 144.44 |
| 'Blaze' | 113.54 | 124.38 | 142.43 |
| 'Shasta' | 89.24 | 96.60 | 101.18 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE XVI

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND AGE ON THE OVER-ALL MEAN FLOWER DIAMETER IN MILLIMETERS FOR THE THREE CHRYSANTHEMUM CULTIVARS, EXPERIMENT II

| Age* | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 1 | 112.43 | 124.24 | 126.59 |
| 2 | 105.90 | 114.03 | 134.72 |
| 3 | 102.36 | 113.13 | 126.74 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE XVII

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER, EXPERIMENT II

| Source of Variation | df | Stage 1 MS | Stage 2 MS |
|---|---|---|---|
| Total | 215 | | |
| Trial (T) | 1 | 16.67 | 22.69 |
| Foot-candles (L) | 1 | 150.00 | 37.50 |
| Error (a) TL | 1 | .46 | 1.85 |
| Cultivar (CV) | 2 | 17,189.70* | 23,422.33** |
| CV x L | 2 | 323.26 | 9.37 |
| Error (b) TCV + TCVL | 4 | 1,456.48 | 741.09 |
| Age (A) | 2 | 1,878.59** | 2,741.78** |
| A x T | 2 | 48.26 | 31.37 |
| A x L | 2 | 13.54 | 10.76 |
| A x T x L | 2 | 2.20 | 54.98 |
| A x CV | 4 | 674.42** | 1,859.49** |
| A x T x CV | 4 | 337.15** | 412.96** |
| A x CV x L | 4 | 4.51 | 14.93 |
| A x T x CV x L | 4 | .81 | 46.64 |
| Error (c) A by F within CV, L R, T, combinations | 96 | 28.65 | 25.52 |
| Row (R) | 1 | 1,837.50** | 1,022.69** |
| R x T | 1 | 16.67 | 66.67 |
| R x CV | 2 | 19.79 | 59.14 |
| R x L | 1 | 150.00 | 1.85 |
| R x CV x T | 2 | 21.87 | 207.29** |
| R x CV x L | 2 | 13.54 | 81.37 |
| R x L x T | 1 | 104.17 | .46 |
| R x CV x L X T | 2 | 108.68 | 4.98 |
| A x R | 2 | 1.04 | 10.53 |
| A x R x T | 2 | 32.29 | 2.43 |
| A x R x CV | 4 | 31.25 | 29.70 |
| A x R x L | 2 | 4.51 | 49.42 |
| A x R x CV x T | 4 | 8.33 | 29.51 |
| A x R x CV x L | 4 | 13.89 | 43.52 |
| A x R x L x T | 2 | 1.04 | 15.39 |
| A x R x CV x L x T | 4 | 9.72 | 44.91 |
| Flowers in CV in F | 48 | 42.36 | 27.78 |
| Over-all Mean | | 106.90 | 117.13 |

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

TABLE XVIII

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT II

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 215 | |
| Trials (T) | 1 | 4.17 |
| Cultivar (CV) | 2 | 42,928.56* |
| Error (a) | 2 | 448.26 |
| CVT | | |
| Age (A) | 2 | 1,557.75** |
| A x CV | 4 | 358.10** |
| A x R | 6 | 16.40 |
| A x CV x R | 12 | 14.20 |
| A x T | 2 | 273.26** |
| A x R x T | 6 | 18.94 |
| A x CV x T | 4 | 105.90** |
| A x R x CV x T | 12 | 12.46 |
| Error (b) | 96 | 22.40 |
| A by F within CV, R, T, combinations | | |
| Row (R) | 3 | 42.88 |
| R x CV | 6 | 26.12 |
| R x T | 3 | 6.33 |
| R x CV x T | 6 | 49.50 |
| Flowers in CV and R | 48 | 37.50 |
| Over-all Mean | | 129.35 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

only stage three. A three factor interaction of age by trial by cultivar was significant at the 1% level for stages one and two. Row by cultivar by trial was significant for stage two.

The three stages were not compared statistically for flower diameter. Stage one, however, had a mean flower diameter of 106.90 millimeters. Those cut in stage two had a mean flower diameter of 117.13 millimeters and stage three flowers had a mean flower diameter of 129.35 millimeters. Since chrysanthemums are normally cut at stage three, cutting earlier at stage two caused a 9.45% decrease in flower diameter and cutting at stage one caused a 17.36% decrease in flower diameter.

## Experiment III

In this experiment chrysanthemum flowers of the three cultivars cut in stages one and two were opened under light intensities of 400 and 600 foot-candles. The over-all average number of days to open for buds cut in stage one was 10.29 and for stage two, 5.06 days. These and other bud opening data for each cultivar, stage of flower bud development at cutting, and light intensity are given in Table XIX. The over-all average for each light intensity (600 F.C.) caused the flowers to open slightly faster than those in the lower light intensity (400 F.C.). Flowers of the cultivar 'Shasta' opened slightly faster than did those of 'Blaze' and 'Yellow Shoesmith'.

Data on cut flower life of the three cultivars, two stages of flower bud development at cutting, and light intensity are shown in Table XX. Stage one had a mean cut flower life of 18.19 days at 400 foot-candles, and 19.39 days at 600 foot-candles. Stage two had a mean

TABLE XIX

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE AVERAGE NUMBER OF DAYS REQUIRED FOR FLOWER OPENING OF CHRYSANTHEMUMS, EXPERIMENT III

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 400 F.C. | 10.50 | 11.67 | 9.33 | 10.50 | 4.33 | 6.50 | 4.33 | 5.06 |
| 600 F.C. | 10.25 | 11.00 | 9.00 | 10.08 | 4.41 | 6.75 | 4.00 | 5.06 |
| Average | 10.38 | 11.33 | 9.17 | 10.29 | 4.38 | 6.63 | 4.17 | 5.06 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

TABLE XX

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE CUT FLOWER LIFE IN DAYS OF CHRYSANTHEMUMS, EXPERIMENT III

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 400 F.C. | 16.33 | 15.33 | 22.92 | 18.19 | 16.25 | 17.00 | 23.75 | 19.00 |
| 600 F.C. | 18.50 | 15.83 | 23.83 | 19.39 | 16.50 | 16.75 | 24.83 | 19.36 |
| Average | 17.42 | 15.58 | 23.38 | 18.79 | 16.38 | 16.88 | 24.29 | 19.18 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

cut flower life of 19.00 days at 400 foot-candles and 19.36 days at 600 foot-candles. Flowers that were opened under the higher light intensity had a cut flower life of 19.38 days, while flowers that opened under the lower light intensity had a cut flower life of 18.60 days. Flowers from the lower light intensity had a 4.02% decrease in cut flower life.

A statistical analysis of experiment three for days to open and cut flower life is shown in Table XXI. The analysis shows that light intensity had no significant effect on days to open and cut flower life. Trial was significant at the 1% level for days to open. Bud stage at cutting was also significant at the 1% level for days to open. Cultivar was significant at the 1% level both for days to open and cut flower life.

Figure 15 shows the effect of trial on cut flower life for the three cultivars when flowers were cut in stage three of flower development. Flowers of the cultivar 'Yellow Shoesmith' had a mean cut flower life in trial one of 20.00 days and in trial two, 30.58 days (over-all mean for both trials was 25.29 days), whereas those of the cultivar 'Blaze' had a mean cut flower life in trial one of 19.33 days and in trial two, 25.08 days (over-all mean for both trials was 22.21 days). Flowers of the cultivar 'Shasta' had a mean cut flower life in trial one of 18.75 days and in trial two, 38.41 days (over-all mean for both trials was 28.58 days). The mean cut flower life for all cultivars in trial one was 19.36 days and 31.36 days for trial two. Table XXII shows the statistical analysis for the cut flower life discussed above for the flowers opened on the plant (stage three). Trial, cultivar and the two factor interaction of trial by cultivar were all significant at the 1% level.

TABLE XXI

ANALYSIS OF VARIANCE FOR DAYS TO OPEN AND FOR CUT FLOWER LIFE, EXPERIMENT III

| Source of Variation | df | Days To Open MS | Cut Flower Life MS |
|---|---|---|---|
| Total | 143 | | |
| Trial (T) | 1 | 62.67* | 2,601.00 |
| Foot Candles (L) | 1 | 1.56 | 21.78 |
| Error (a) TL | 1 | 0.06 | 66.69 |
| Row (R) | 1 | 0.84 | 75.11 |
| R x L | 1 | 0.84 | 6.25 |
| Error (b) TR x TRL | 2 | 1.81 | 88.90 |
| Stage (S) | 1 | 987.01** | 5.44** |
| Cultivar (CV) | 2 | 67.38** | 851.17** |
| S x CV | 2 | 5.51 | 18.84 |
| S x L | 1 | 1.56 | 6.25 |
| CV x L | 2 | .19 | 3.97 |
| S x CV x L | 2 | .65 | 3.27 |
| Error (c) TS + TCV + TSCV + TSL + TCVL + TSCVL + RS + RCV + RSCV + RSL + RCVL + RSCVL + TRS + TRCV + TRSCV + TRSL + TRCVL + TRSCVL | 30 | 2.05 | 124.15 |
| Flowers in CV in R | 96 | .53 | 3.63 |
| Over-all Mean | | 7.67 | 18.99 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

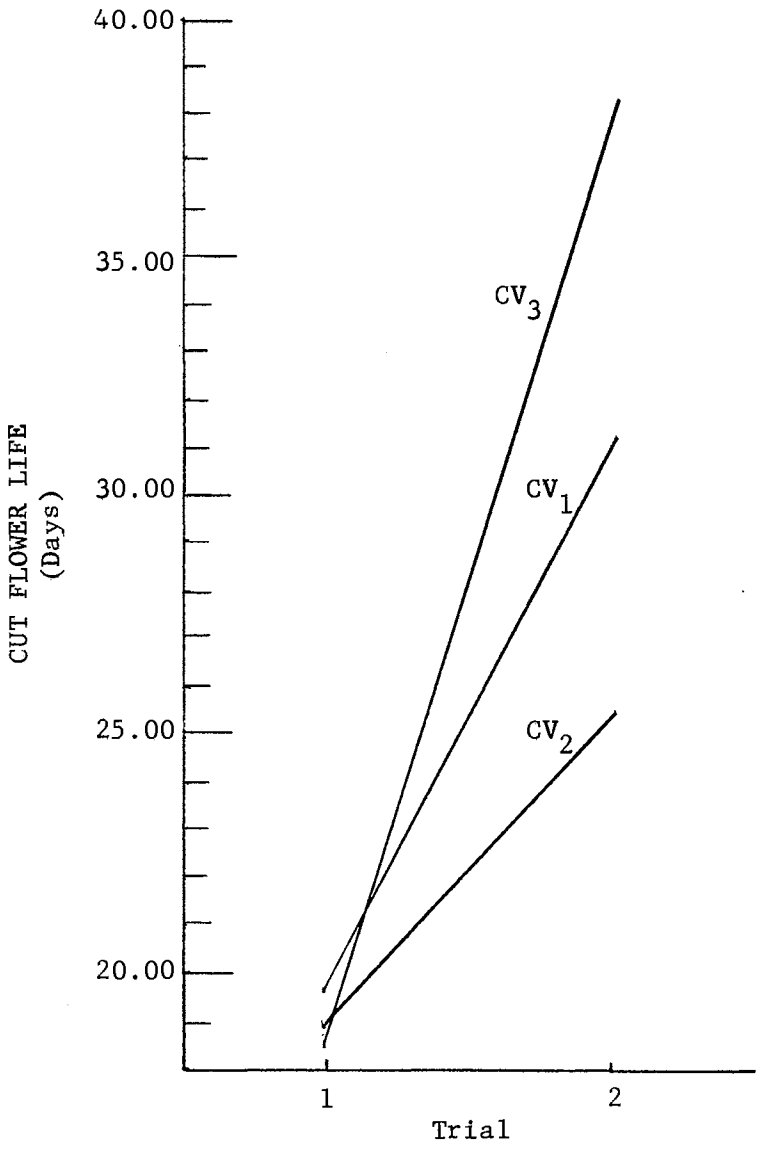



Figure 15. The Effect of Trial by Cultivar Interaction on Cut Flower Life of Flowers Cut in Stage Three* of Flower Development, Experiment III

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stage three flower development.

TABLE XXII

ANALYSIS OF VARIANCE FOR CUT FLOWER LIFE FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT III

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 71 | |
| Trials (T) | 1 | 2,592.00** |
| Rows in Lab (R) | 3 | 9.73 |
| Error (a) TR | 3 | 14.19 |
| Cultivar (CV) | 2 | 243.93** |
| CV x T | 2 | 299.54** |
| Error (b) RCV + TRCV | 12 | 1.71 |
| Flowers in CV in R | 48 | 0.82 |
| Over-all Mean | | 25.36 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

Cut flower life data for flowers from the three flower development stages were not compared statistically. The cut flower life, however, for stages one, two, and three of the three cultivars is shown in Table XXIII. In all but one case, flowers cut in stage three lasted longer than flowers cut in stage two, and stage two flowers lasted longer than did flowers cut in stage one. The one exception was with the cultivar 'Yellow Shoesmith', (stage two). Over all cultivars, stage one flowers had a mean cut flower life of 18.79 days; those cut in stage two had a mean cut flower life of 19.18 days; and those cut in stage three had a mean cut flower life of 25.36 days. Since chrysanthemums are normally cut at stage three flower development, cutting earlier at stage two caused a 24.35% decrease in cut flower life and cutting at stage one caused a 25.88% decrease in cut flower life.

The measurements that were made on flower diameter showed that there was a slight decrease in flower diameter with higher light intensity. Mean flower diameter of stage one flowers was 105.05 millimeters at 400 foot-candles and 104.72 millimeters at 600 foot-candles. For stage two the mean flower diameter was 122.31 millimeters at 400 foot-candles and 120.42 millimeters at 600 foot-candles. Table XXIV shows the mean flower diameter for all three cultivars and stages. Flowers of the cultivar 'Yellow Shoesmith' had the largest flower diameter for stages one and two, while 'Blaze' had the largest flower diameter for stage three. 'Shasta' had the smallest diameter for all three stages. The mean flower diameter when the flowers opened (stage three), one week after the flowers opened, and two weeks after the flowers opened is shown in Table XXV. This table shows that stages one and three flowers increased in flower diameter during the first week after they

TABLE XXIII

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE MEAN NUMBER OF DAYS FOR CUT FLOWER LIFE OF CHRYSANTHEMUM FLOWERS, EXPERIMENT III

| Cultivar | Mean Number of Days for Cut Flower Life | | |
|---|---|---|---|
| | Stage 1* | Stage 2* | Stage 3* |
| 'Yellow Shoesmith' | 17.42 | 16.38 | 25.29 |
| 'Blaze' | 15.58 | 16.88 | 22.21 |
| 'Shasta' | 23.38 | 24.29 | 28.58 |
| Over-all Average | 18.79 | 19.18 | 25.36 |

*See page 18 for explanation of stages of flower development.

TABLE XXIV

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE OVER-ALL MEAN* OF FLOWER DIAMETER IN MILLIMETERS, EXPERIMENT III

| Cultivar | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 'Yellow Shoesmith' | 110.63 | 135.90 | 152.85 |
| 'Blaze' | 115.55 | 132.22 | 142.85 |
| 'Shasta' | 88.47 | 95.97 | 99.17 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE XXV

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND AGE ON THE OVER-ALL MEAN FLOWER DIAMETER IN MILLIMETERS FOR THE THREE CHRYSANTHEMUM CULTIVARS, EXPERIMENT III

| Age* | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 1 | 109.10 | 125.97 | 132.43 |
| 2 | 106.11 | 124.38 | 132.71 |
| 3 | 99.44 | 113.75 | 129.72 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

were considered opened (stage three) and decreased in flower diameter the second week. Stage two flower diameter decreased from the time the flowers were considered opened.

Table XXVI shows the analysis of variance pertaining to flower diameter for flowers cut in stage one and stage two. Stage three flowers were also analyzed for flower diameter in Table XXVII. The analysis showed that light intensity during opening of the buds had no significant effect on the three measurements for flower diameter. A main effect of cultivar was present at the 1% level for stage two and at the 5% level for stages one and three. A main effect of age on flower diameter was significant at the 1% level for stages one and two and at the 5% level for stage three. A two factor interaction of age by cultivar for flower diameter was significant at the 1% level for all three stages. Trial was significant at the 5% level for stage two. Age by trial was significant at the 5% level for stage one and was significant at the 1% level for stage two. The three factor interactions of age by trial by cultivar and age by cultivar by light intensity were significant for stage one. Row was also significant at the 5% level for stage one. Stage two had a three factor interaction of row by cultivar by trial which was significant at the 1% level.

The three stages were not compared statistically for flower diameter. Stage one, however, had a mean flower diameter of 104.88 millimeters. Those cut in stage two had a mean flower diameter of 121. 36 millimeters and stage three flowers had a mean flower diameter of 131.67 millimeters. Since chrysanthemums are normally cut at stage three, cutting earlier at stage two caused a 7.73% decrease in flower diameter and cutting at stage one caused a 20.35% decrease in flower diameter.

TABLE XXVI

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER, EXPERIMENT III

| Source of Variation | df | Stage 1 MS | Stage 2 MS |
|---|---|---|---|
| Total | 215 | | |
| Trial (T) | 1 | 402.89 | 651.04* |
| Foot-candles (L) | 1 | 5.67 | 194.56 |
| Error (a) TL | 1 | 41.78 | 2.89 |
| Cultivar (CV) | 2 | 14,982.75* | 35,064.70** |
| CV x L | 2 | 164.00 | 114.70 |
| Error (b) TCV + TCVL | 4 | 1,271.29 | 676.97 |
| Age (A) | 2 | 1,758.45** | 3,177.89** |
| A x T | 2 | 68.17* | 702.43** |
| A x L | 2 | 49.42 | 28.59 |
| A x T x L | 2 | 17.48 | 78.59* |
| A x CV | 4 | 367.48** | 865.74** |
| A x T x CV | 4 | 71.64** | 1.74 |
| A x CV x L | 4 | 42.13* | 34.14 |
| A x T x CV x L | 4 | 17.13 | 30.32 |
| Error (c) A by F within CV, L R, T, combinations | 96 | 16.84 | 25.17 |
| Row (R) | 1 | 255.67* | 14.00 |
| R x T | 1 | 19.56 | .12 |
| R x CV | 2 | 146.64 | 88.31 |
| R x L | 1 | 41.78 | 1.04 |
| R x CV x T | 2 | 64.00 | 215.39** |
| R x CV x L | 2 | 5.67 | 78.12 |
| R x L x T | 1 | 51.04 | 19.56 |
| R x CV x L x T | 2 | 37.85 | 20.95 |
| A x R | 2 | 11.92 | 10.53 |
| A x R x T | 2 | 31.37 | 43.86 |
| A x R x CV | 4 | 13.31 | 18.17 |
| A x R x L | 2 | 5.67 | 31.60 |
| A x R x CV x T | 4 | 15.39 | 16.44 |
| A x R x CV x L | 4 | 35.19 | 40.97 |
| A x R x L x T | 2 | 14.93 | 18.17 |
| A x R x CV x L x T | 4 | 4.86 | 13.31 |
| Flowers in CV in F | 48 | 49.31 | 36.11 |
| Over-all Mean | | 104.88 | 121.37 |

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

TABLE XXVII

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT III

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 215 | |
| Trials (T) | 1 | 2,467.13 |
| Cultivar (CV) | 2 | 58,675.12* |
| Error (a) | 2 | 1,376.50 |
| CVT | | |
| Age (A) | 2 | 195.95* |
| A x CV | 4 | 637.27** |
| A x R | 6 | 21.57 |
| A x CV x R | 12 | 20.06 |
| A x T | 2 | 35.53 |
| A x R x T | 6 | 22.38 |
| A x CV x T | 4 | 46.99 |
| A x R x CV x T | 12 | 13.73 |
| Error (b) | 96 | 40.74 |
| A by F within CV, R, T, combinations | | |
| Row (R) | 3 | 9.41 |
| R x CV | 6 | 87.74 |
| R x T | 3 | 80.40 |
| R x CV x T | 6 | 82.37 |
| Flowers in CV and R | 48 | 33.10 |
| Over-all Mean | | 131.62 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

## Experiment IV

In this experiment chrysanthemum flowers of the three cultivars cut in stages one and two were opened under light intensities of 600 and 800 foot-candles. The over-all average number of days to open for buds cut in stage one was 10.21 and for stage two, 5.04 days. These and other bud opening data for each cultivar, stage at cutting, and light intensity are given in Table XXVIII. The over-all average for each light intensity showed that the lower light intensity (600 F.C.) caused the flowers to open slightly faster than those in the higher light intensity (800 F.C.). Flowers of the cultivar 'Shasta' opened slightly faster than did those of 'Blaze' and 'Yellow Shoesmith'.

Data on cut flower life of the three cultivars, two stages of flower bud development at cutting, and light intensity are shown in Table XXIX. Differences due to light intensity were slight. Stage one had a mean cut flower life of 19.45 days at 600 foot-candles and 18.97 days at 800 foot-candles. Stage two had a mean cut flower life of 19.36 days at 600 foot-candles and 19.17 days at 800 foot-candles. Flowers that were opened under the lower light intensity had a cut flower life of 19.37 days, while flowers that opened under the higher light intensity had a cut flower life of 19.10 days. Flowers from the higher light intensity had a 1.39% decrease in cut flower life.

A statistical analysis of experiment three for days to open and cut flower life is shown in Table XXX. The analysis showed that light intensity had no significant effect on days to open and cut flower life. Bud stage at cutting was significant at the 1% level for days to open. Cultivar was significant at the 1% level and trial was significant at the 5% level both for days to open and cut flower life.

TABLE XXVIII

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE AVERAGE NUMBER OF DAYS REQUIRED FOR FLOWER OPENING OF CHRYSANTHEMUMS, EXPERIMENT IV

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 600 F.C. | 10.25 | 11.00 | 9.00 | 10.08 | 4.42 | 6.75 | 4.00 | 5.06 |
| 800 F.C. | 10.08 | 11.67 | 9.25 | 10.33 | 4.58 | 6.58 | 3.92 | 5.03 |
| Average | 10.17 | 11.33 | 9.13 | 10.21 | 4.50 | 6.67 | 3.96 | 5.04 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

TABLE XXIX

EFFECTS OF CULTIVAR, STAGE OF FLOWER BUD DEVELOPMENT AT CUTTING, AND LIGHT INTENSITY ON THE CUT FLOWER LIFE IN DAYS OF CHRYSANTHEMUMS, EXPERIMENT IV

| | Stage 1* | | | | Stage 2* | | | |
|---|---|---|---|---|---|---|---|---|
| | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average | $CV_1$ | $CV_2$ | $CV_3$ | Over-all Average |
| 600 F.C. | 18.70 | 15.83 | 23.83 | 19.45 | 16.50 | 16.75 | 24.83 | 19.36 |
| 800 F.C. | 17.75 | 15.08 | 24.08 | 18.97 | 16.25 | 16.75 | 24.50 | 19.17 |
| Average | 18.23 | 15.46 | 23.96 | 19.21 | 16.38 | 16.75 | 24.67 | 19.27 |

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stages of flower bud development.

TABLE XXX

ANALYSIS OF VARIANCE FOR DAYS TO OPEN AND FOR CUT FLOWER LIFE, EXPERIMENT IV

| Source of Variation | df | Days To Open MS | Cut Flower Life MS |
|---|---|---|---|
| Total | 143 | | |
| Trial (T) | 1 | 78.03* | 3,239.51* |
| Foot Candles (L) | 1 | 0.44 | 3.06 |
| Error (a) TL | 1 | 0.44 | 5.06 |
| Row (R) | 1 | 1.00 | 115.56 |
| R x L | 1 | 0.69 | 0.17 |
| Error (b) TR x TRL | 2 | 1.62 | 99.28 |
| Stage (S) | 1 | 961.00** | 0.17 |
| Cultivar (CV) | 2 | 75.58** | 946.58** |
| S x CV | 2 | 3.00 | 32.19 |
| S x L | 1 | 0.69 | 0.34 |
| CV x L | 2 | .19 | 0.58 |
| S x CV x L | 2 | 1.03 | 1.44 |
| Error (c) TS + TCV + TSCV + TSL + TCVL + TSCVL + RS + RCV + RSCV + RSL + RCVL + RSCVL + TRS + TRCV + TRSCV + TRSL + TRCVL + TRSCVL | 30 | 2.00 | 60.91 |
| Flowers in CV in R | 96 | .44 | 2.90 |
| Over-all Mean | | 7.63 | 19.23 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

Figure 16 shows the effect of trial on cut flower life for the three cultivars when flowers were cut in stage three of flower development. Flowers of the cultivar 'Yellow Shoesmith' had a mean cut flower life in trial one of 20.10 days and in trial two, 30.56 days (over-all mean for both trials was 25.33 days), whereas flowers of the cultivar 'Blaze' had a mean cut flower life in trial one of 19.45 days and in trial two, 24.97 days (over-all mean for both trials was 22.21 days). Flowers of the cultivar 'Shasta' had a mean cut flower life in trial one of 17.95 days and in trial two, 38.63 days (over-all mean for both trials was 28.29 days). The mean cut flower life for all cultivars in trial one was 19.14 days and 31.42 days for trial two. Table XXXI shows the statistical analysis for the cut flower life discussed above for the flowers opened on the plant (stage three). Trial, cultivar, and the two factor interaction of trial by cultivar were all significant at the 1% level.

Cut flower life data for flowers from the three flower development stages were not compared statistically. Cut flower life, however, for stages one, two, and three of the three cultivars is shown in Table XXXII. In all but one case, flowers cut in stage three lasted longer than flowers cut in stage two, and stage two flowers lasted longer than did flowers cut in stage one. The one exception was with the cultivar 'Yellow Shoesmith', (stage two). Over all cultivars, stage one flowers had a mean cut flower life of 19.18 days; those cut in stage two had a mean cut flower life of 19.27 days; and those cut in stage three had a mean cut flower life of 25.28 days. Since chrysanthemums are normally cut at stage three flower development, cutting earlier at stage two caused a 23.77% decrease in cut flower life and cutting at stage one caused a 24.13% decrease in cut flower life.

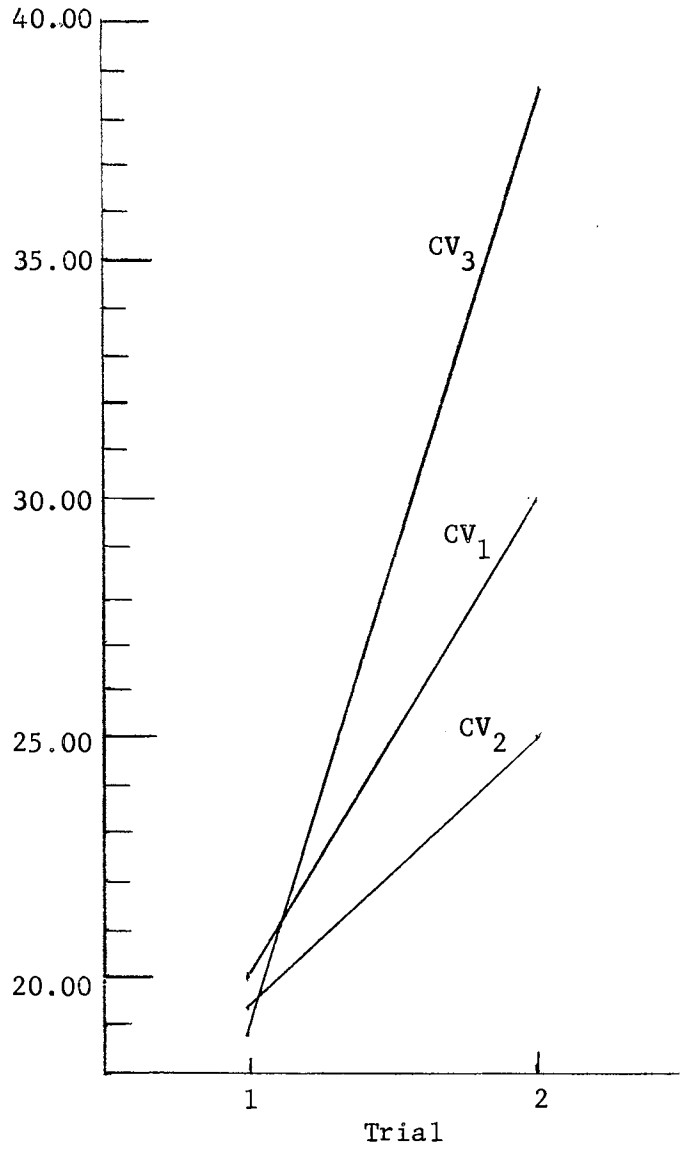



Figure 16. The Effect of Trial by Cultivar Interaction on Cut Flower Life of Flowers Cut in Stage Three* of Flower Development, Experiment IV

$CV_1$ = 'Yellow Shoesmith'

$CV_2$ = 'Blaze'

$CV_3$ = 'Shasta'

*See page 18 for explanation of stage three flower development.

TABLE XXXI

ANALYSIS OF VARIANCE FOR CUT FLOWER LIFE FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT IV

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 71 | |
| Trials (T) | 1 | 2,713.39** |
| Rows in Lab (R) | 3 | 18.41 |
| Error (a) TR | 3 | 23.95 |
| Cultivar (CV) | 2 | 222.10** |
| CV x T | 2 | 244.68** |
| Error (b) RCV + TRCV | 12 | 1.64 |
| Flowers in CV in R | 48 | 1.14 |
| Over-all Mean | | 25.28 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

TABLE XXXII

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE MEAN NUMBER OF DAYS FOR CUT FLOWER LIFE OF CHRYSANTHEMUM FLOWERS, EXPERIMENT IV

| Cultivar | Mean Number of Days for Cut Flower Life | | |
|---|---|---|---|
| | Stage 1* | Stage 2* | Stage 3* |
| 'Yellow Shoesmith' | 18.17 | 16.38 | 25.33 |
| 'Blaze' | 15.42 | 16.75 | 22.21 |
| 'Shasta' | 23.96 | 24.67 | 28.29 |
| Over-all Average | 19.18 | 19.27 | 25.28 |

*See page 18 for explanation of stages of flower development.

The measurements that were made on flower diameter showed that there was a slight decrease in flower diameter with the higher light intensity. The mean flower diameter of stage one flowers was 106.99 millimeters at 600 foot-candles and 106.11 millimeters at 800 foot-candles. For stage two the mean flower diameter was 124.16 millimeters at 600 foot-candles and 121.71 millimeters at 800 foot-candles. Table XXXIII shows the mean flower diameter for all three cultivars and stages. In each cultivar, flower diameter increased with stage of bud opening at cutting. Flowers of the cultivar 'Yellow Shoesmith' had the largest flower diameter for stages one and two, while 'Blaze' had the largest flower diameter for stage three. Flowers of the cultivar 'Shasta' had the smallest diameter for all three stages. The mean flower diameter when the flower opened (stage three), one week after the flower opened, and two weeks after the flower opened is shown in Table XXXIV. This table shows that stages one and two flower diameters decreased from the time the flowers were considered opened (stage three). Stage three flowers increased in flower diameter during the first week after they were considered opened and decreased in flower diameter the second week.

Table XXXV shows the analysis of variance pertaining to flower diameter for flowers cut in stage one and stage two. Stage three flowers were also analyzed for flower diameter in Table XXXVI. The analysis showed that light intensity during opening of the buds had no significant effect on the three measurements for flower diameter. A main effect of cultivar was present at the 1% level for stage two and at the 5% level for stages one and three. A main effect of age on flower diameter was significant at the 1% level for all three stages.

TABLE XXXIII

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND CULTIVAR ON THE OVER-ALL MEAN* OF FLOWER DIAMETER IN MILLIMETERS, EXPERIMENT IV

| Cultivar | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 'Yellow Shoesmith' | 112.08 | 136.18 | 152.50 |
| 'Blaze' | 116.60 | 134.38 | 143.89 |
| 'Shasta | 90.97 | 98.26 | 99.51 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE XXXIV

THE EFFECTS OF STAGE OF FLOWER DEVELOPMENT AT CUTTING AND AGE ON THE OVER-ALL MEAN FLOWER DIAMETER IN MILLIMETERS FOR THE THREE CHRYSANTHEMUM CULTIVARS, EXPERIMENT IV

| Age* | Stage 1** | Stage 2** | Stage 3** |
|---|---|---|---|
| 1 | 110.90 | 127.50 | 132.08 |
| 2 | 108.06 | 126.11 | 133.75 |
| 3 | 100.69 | 115.21 | 130.07 |

*The over-all mean of flower diameter measurements made at the following times: (1) when the flower opened (stage 3); (2) one week after the flower opened; and (3) two weeks after the flower opened.

**See page 18 for explanation of stages of flower development.

TABLE XXXV

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER, EXPERIMENT IV

| Source of Variation | df | Stage 1 MS | Stage 2 MS |
|---|---|---|---|
| Total | 215 | | |
| Trial (T) | 1 | 616.78 | 350.12 |
| Foot-candles (L) | 1 | 41.78 | 325.12 |
| Error (a) TL | 1 | 51.04 | 126.04 |
| Cultivar (CV) | 2 | 13,472.34* | 32,939.35** |
| CV x L | 2 | 66.78 | 168.52 |
| Error (b) TCV + TCVL | 4 | 832.52 | 332.87 |
| Age (A) | 2 | 1,998.03** | 3,262.62** |
| A x T | 2 | 209.14** | 966.78** |
| A x L | 2 | 42.48 | 184.14 |
| A x T x L | 2 | 44.79** | 69.79** |
| A x CV | 4 | 460.19** | 1,199.77** |
| A x T x CV | 4 | 90.74** | 7.06 |
| A x CV x L | 4 | 20.60 | 26.50 |
| A x T x CV x L | 4 | 6.25 | 22.22 |
| Error (c) A by F within CV, L R, T, combinations | 96 | 16.72 | 25.29 |
| Row (R) | 1 | 72.34 | 376.04** |
| R x T | 1 | 84.37 | 41.78 |
| R x CV | 2 | 84.14 | 66.67 |
| R x L | 1 | 5.67 | 26.04** |
| R x CV x T | 2 | 56.60** | 197.69** |
| R x CV x L | 2 | 317.48** | 26.39 |
| R x L x T | 1 | 61.23 | 26.04** |
| R x CV x L x T | 2 | 84.83 | 176.39** |
| A x R | 2 | 25.12 | 17.01 |
| A x R x T | 2 | 21.87 | 42.48 |
| A x R x CV | 4 | 27.55 | 8.68 |
| A x R x L | 2 | 82.06 | 9.37 |
| A x R x CV x T | 4 | 5.56 | 15.05 |
| A x R x CV x L | 4 | 19.91 | 32.64 |
| A x R x L x T | 2 | 12.62 | 38.54 |
| A x R x CV x L x T | 4 | 49.77 | 19.10 |
| Flowers in CV in F | 48 | 44.33 | 25.46 |
| Over-all Mean | | 106.55 | 122.94 |

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

TABLE XXXVI

ANALYSIS OF VARIANCE FOR FLOWER DIAMETER FOR FLOWERS CUT IN STAGE THREE OF FLOWER DEVELOPMENT, EXPERIMENT IV

| Source of Variation | df | Stage 3 MS |
|---|---|---|
| Total | 215 | |
| Trials (T) | 1 | 2,709.37 |
| Cultivar (CV) | 2 | 58,209.84* |
| Error (a) | 2 | 1,494.10 |
| CVT | | |
| Age (A) | 2 | 244.56** |
| A x CV | 4 | 577.03** |
| A x R | 6 | 16.94 |
| A x CV x R | 12 | 16.76 |
| A x T | 2 | 62.85 |
| A x R x T | 6 | 23.49 |
| A x CV x T | 4 | 33.51 |
| A x R x CV x T | 12 | 10.59 |
| Error (b) | 96 | 30.09 |
| A by F within CV, R, T, combinations | | |
| Row (R) | 3 | 16.47 |
| R x CV | 6 | 15.09 |
| R x T | 3 | 29.74 |
| R x CV x T | 6 | 54.43 |
| Flowers in CV and R | 48 | 42.94 |
| Over-all Mean | | 131.97 |

*Significant at the 5 per cent level.

**Significant at the 1 per cent level.

A two factor interaction of age by cultivar for flower diameter was also significant at the 1% level for all three stages. Age by trial was significant at the 1% level for stages one and two. The three factor interactions of age by trial by cultivar and row by cultivar by light intensity were significant for stage one. Row was significant at the 1% level for stage two. Row by cultivar by trial and row by cultivar by light intensity by trial were also significant at the 1% level for stage two.

The three stages were not compared statistically for flower diameter. Stage one, however, had a mean flower diameter of 106.55 millimeters. Those cut in stage two had a mean flower diameter of 122.94 millimeters, and stage three flowers had a mean flower diameter of 131.97 millimeters. Since chrysanthemums are normally cut at stage three, cutting earlier at stage two caused a 7.05% decrease in flower diameter and cutting at stage one caused a 19.26% decrease in flower diameter.

Since the main purpose of this study was to determine the best light intensity for opening chrysanthemum flower buds off the plant, the combined results of the four light intensity experiments are shown in Table XXXVII. Looking at each light intensity experiment separately, the cut flower life increased up to 600 foot-candles and then decreased and the flower diameter increased up to 200 foot-candles and then decreased.

## Experiment V

The effects on cut flower life of opening chrysanthemum flower buds on and off the plant in the greenhouse are shown in Figure 17.

TABLE XXXVII

THE COMBINED RESULTS OF THE FOUR LIGHT INTENSITY EXPERIMENTS
SHOWING THE EFFECT OF LIGHT INTENSITY ON
CUT FLOWER LIFE AND FLOWER DIAMETER

| Experiment | Foot-Candles | Cut Flower Life (Days) | Foot-Candles | Cut Flower Life (Days) |
|---|---|---|---|---|
| I 50 vs 200 | 50 | 25.38 | 200 | 26.01 |
| II 200 vs 400 | 200 | 25.11 | 400 | 26.26 |
| III 400 vs 600 | 400 | 18.60 | 600 | 19.38 |
| IV 600 vs 800 | 600 | 19.37 | 800 | 19.10 |

| Experiment | Foot-Candles | Flower Diameter (Millimeters) | Foot-Candles | Flower Diameter (Millimeters) |
|---|---|---|---|---|
| I 50 vs 200 | 50 | 105.53 | 200 | 109.93 |
| II 200 vs 400 | 200 | 112.64 | 400 | 111.41 |
| III 400 vs 600 | 400 | 113.68 | 600 | 112.57 |
| IV 600 vs 800 | 600 | 115.58 | 800 | 113.91 |

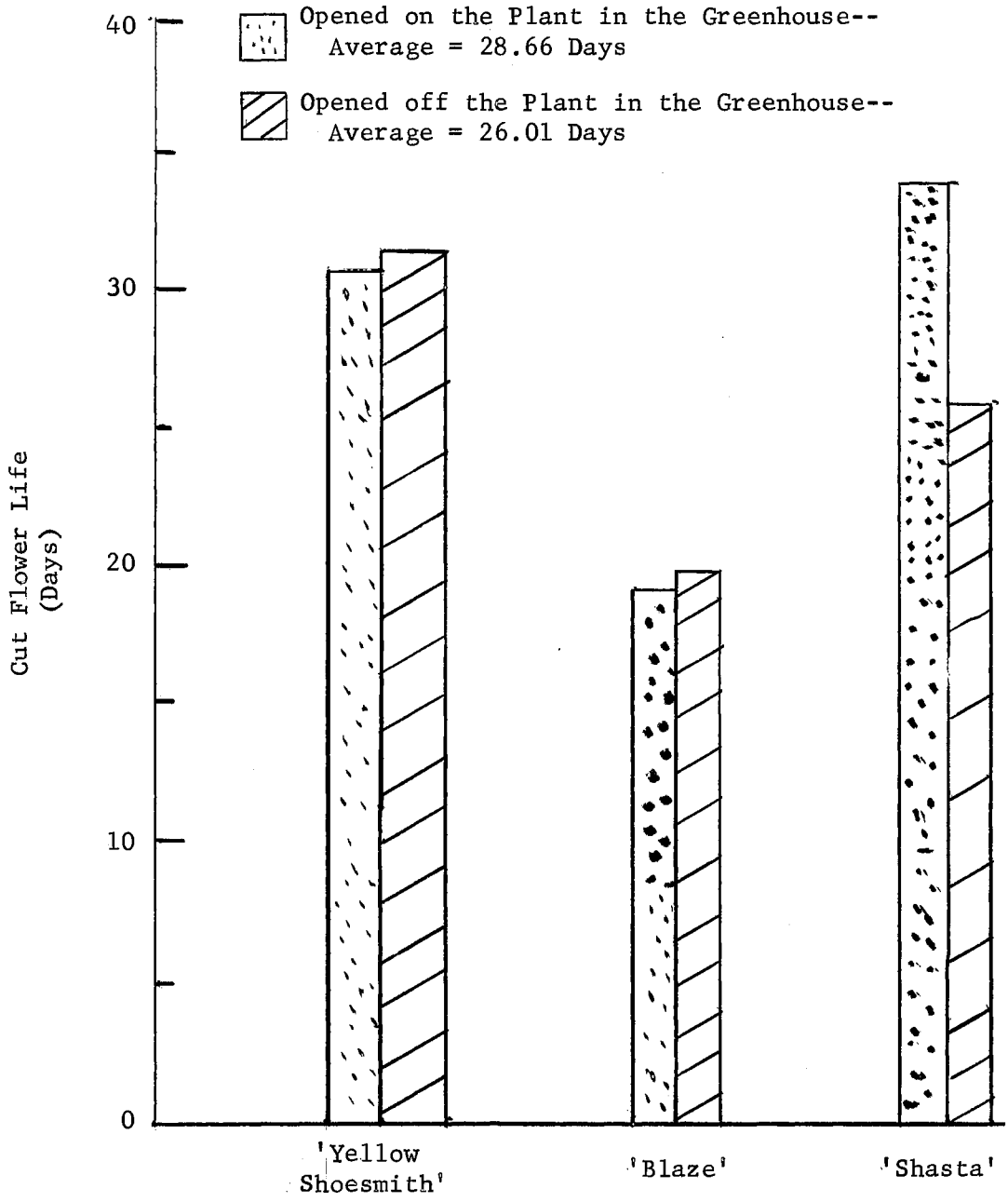



Figure 17. The Effect of Opening of Chrysanthemum Flower Buds On and Off the Plant on Cut Flower Life

The over-all mean cut flower life for the flowers opened on the plant was 28.66 days. The mean for flowers opened off the plant was 26.01 days. Differences in the cultivars 'Yellow Shoesmith' and 'Blaze' were slight, while 'Shasta' flowers opened on the plant lasted several days longer than the flowers opened off the plant.

Opening the flower buds on and off the plant had a slight effect on the flower diameter, Figure 18. Over all cultivars there was a 3.59 per cent loss in diameter by opening the flower buds off the plant.

It was observed that the cultivars 'Yellow Shoesmith' and 'Blaze' had a brighter color when opened off the plant in Everbloom solution. The cultivar 'Shasta', which has a white flower, had no color change whether the buds were opened on or off the plant. Flowers of the cultivar 'Shasta' were grown as a spray type, and when opened off the plant, the flowers were closer together and in a smaller bunch than the flowers opened on the plant.

The results of the four light intensity experiments and the experiment of opening chrysanthemum flower buds on and off the plant in the greenhouse are shown in Table XXXVIII. These stages were not compared statistically for cut flower life or flower diameter. Combining the results of all four light intensity tests, cutting at stage one caused a 26.57% decrease in cut flower life as compared to stage three, and cutting at stage two caused a 20.14% decrease in cut flower life as compared to stage three. Considering flower diameter, cutting at stage one caused a 19.18% decrease in flower diameter, and cutting at stage two caused a 8.74% decrease in flower diameter as compared to stage three. Stage one, which was opened at the greenhouse, however, only had a 9.25% decrease in cut flower life as compared to a 26.57%

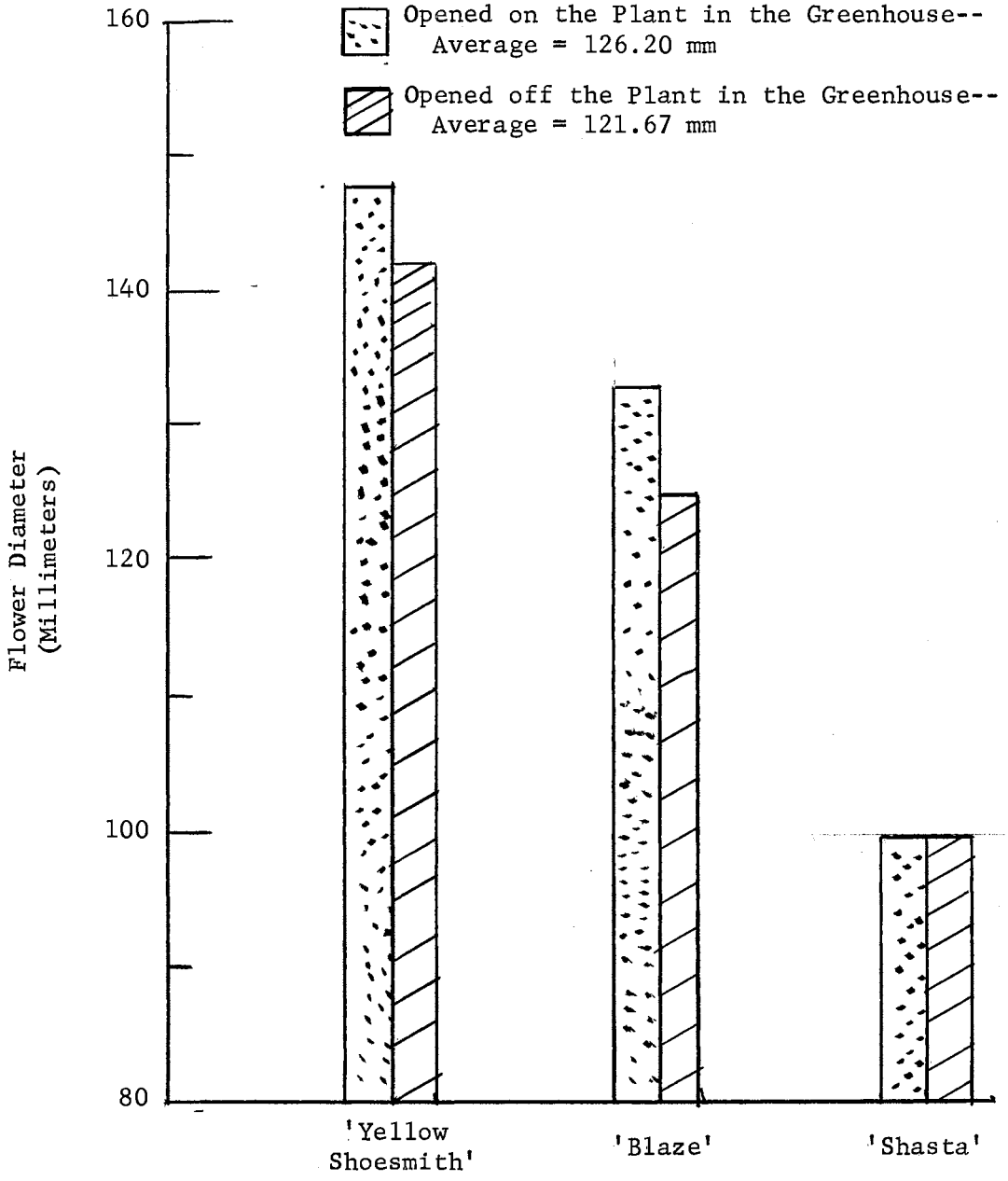



Figure 18. The Effect of Opening of Chrysanthemum Flower Buds On and Off the Plant on Flower Diameter

TABLE XXXVIII

THE RESULTS OF FOUR LIGHT INTENSITY EXPERIMENTS AND A FIFTH EXPERIMENT OF OPENING CHRYSANTHEMUM FLOWER BUDS IN THE GREENHOUSE SHOWING THE PER CENT LOSS IN CUT FLOWER LIFE AND FLOWER DIAMETER WHEN CUTTING CHRYSANTHEMUMS IN THE FLOWER BUD STAGE AS COMPARED TO CHRYSANTHEMUMS OPENED ON THE PLANT

| Experiment | Stage One | % Loss in Cut Flower Life Compared to Stage Three | Stage Two | % Loss in Cut Flower Life Compared to Stage Three | Stage Three |
|---|---|---|---|---|---|
| I 50 vs 200 | 23.59 | 21.52 | 27.79 | 7.55 | 30.06 |
| II 200 vs 400 | 19.56 | 34.73 | 22.51 | 24.89 | 29.97 |
| III 400 vs 600 | 18.79 | 25.88 | 19.18 | 24.35 | 25.36 |
| IV 600 vs 800 | 19.18 | 24.13 | 19.27 | 23.77 | 25.28 |
| V OFF vs ON | 26.01 | 9.25 | | | 28.66 |

| Experiment | Stage One | % Loss in Flower Diameter Compared to Stage Three | Stage Two | % Loss in Flower Diameter Compared to Stage Three | Stage Three |
|---|---|---|---|---|---|
| I 50 vs 200 | 102.01 | 19.73 | 113.45 | 10.73 | 127.08 |
| II 200 vs 400 | 106.90 | 17.36 | 117.13 | 9.45 | 129.35 |
| III 400 vs 600 | 104.88 | 20.35 | 121.36 | 7.73 | 131.67 |
| IV 600 vs 800 | 106.55 | 19.26 | 122.94 | 7.05 | 131.97 |
| V OFF vs ON | 121.67 | 3.59 | | | 126.20 |

decrease in cut flower life of stage one, which was opened in the growth chambers. Also, stage one that was opened in the greenhouse had a 3.59% decrease in flower diameter as compared to 19.18% decrease in flower diameter of stage one that was opened in the growth chambers.

## Experiment VI

An experiment was conducted comparing seven different ways of cutting the stems of chrysanthemum cut flowers. Cut flower life was measured and the results are shown in Figure 19.

A slant cut with the stem crushed one inch had the highest mean for cut flower life, 30.88 days, followed by a slant cut with 30.75 days and a horizontal cut with 30.58 days. The treatment with the lowest cut flower life was the slant cut with four one-inch cuts up the side and had a mean of 28.67 days. The difference between the lowest and the highest cut flower life treatment was 7.12 per cent.

## Experiment VII

This experiment was conducted to determine the most effective way of cutting the stem of the chrysanthemum flower in the woody part of the stem and also in the succulent part of the stem and then compare the results of both methods, Figure 20.

With the stem cuts in the succulent part of the stem, the best treatment was the horizontal cut with a mean cut flower life of 36.50 days followed by the shears with 35.67 days. The lowest mean cut flower life for stems cut in the succulent part of the stem was 34.00 days. This was the slant cut with the stem crushed one inch. The difference between the lowest and highest treatments in the succulent part of the stem was 6.77 per cent.

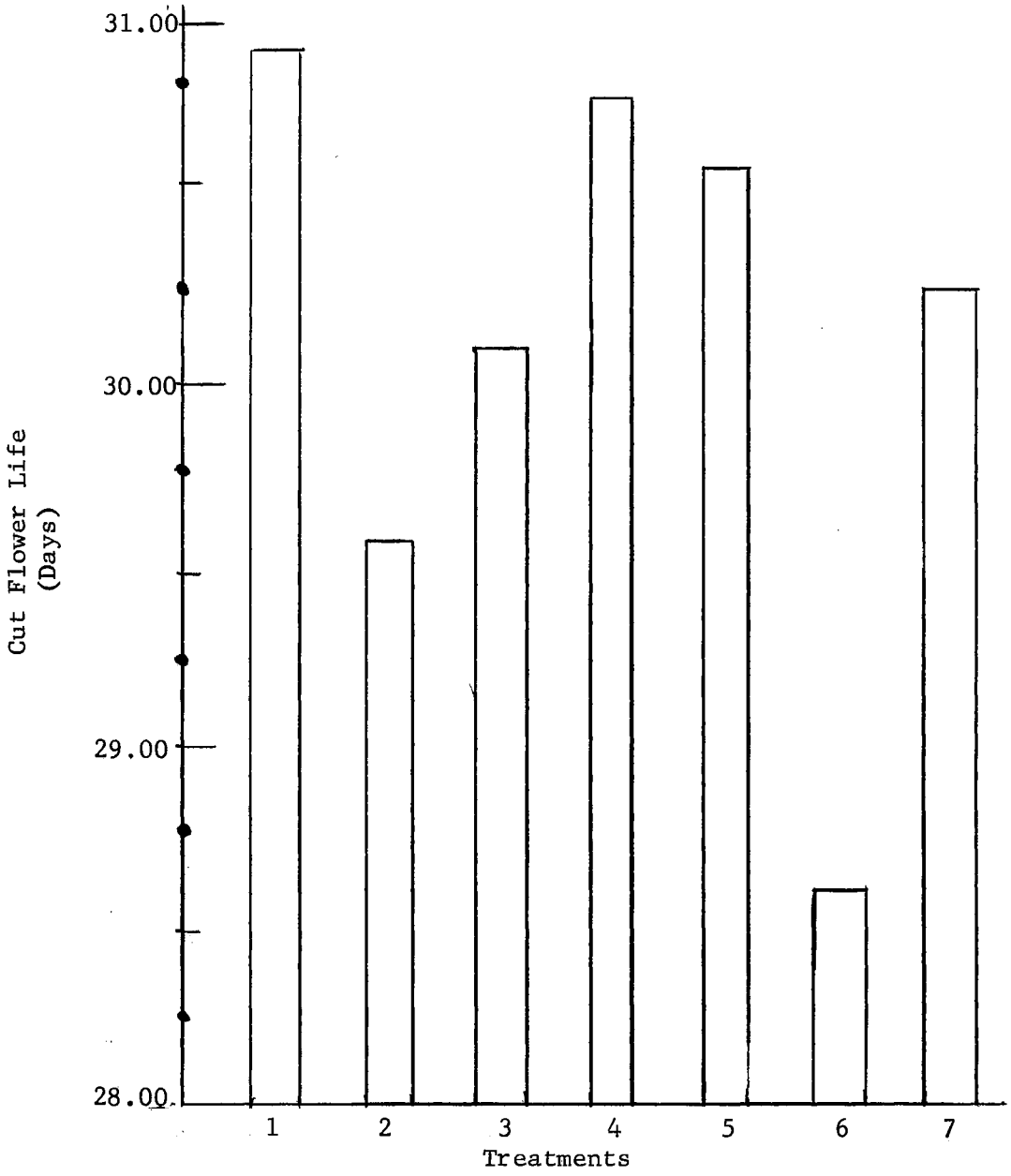



Figure 19. The Effect of Certain Stem Cutting Treatments* on Cut Flower Life of Chrysanthemum Flowers

*See page 30 for explanation of treatments.

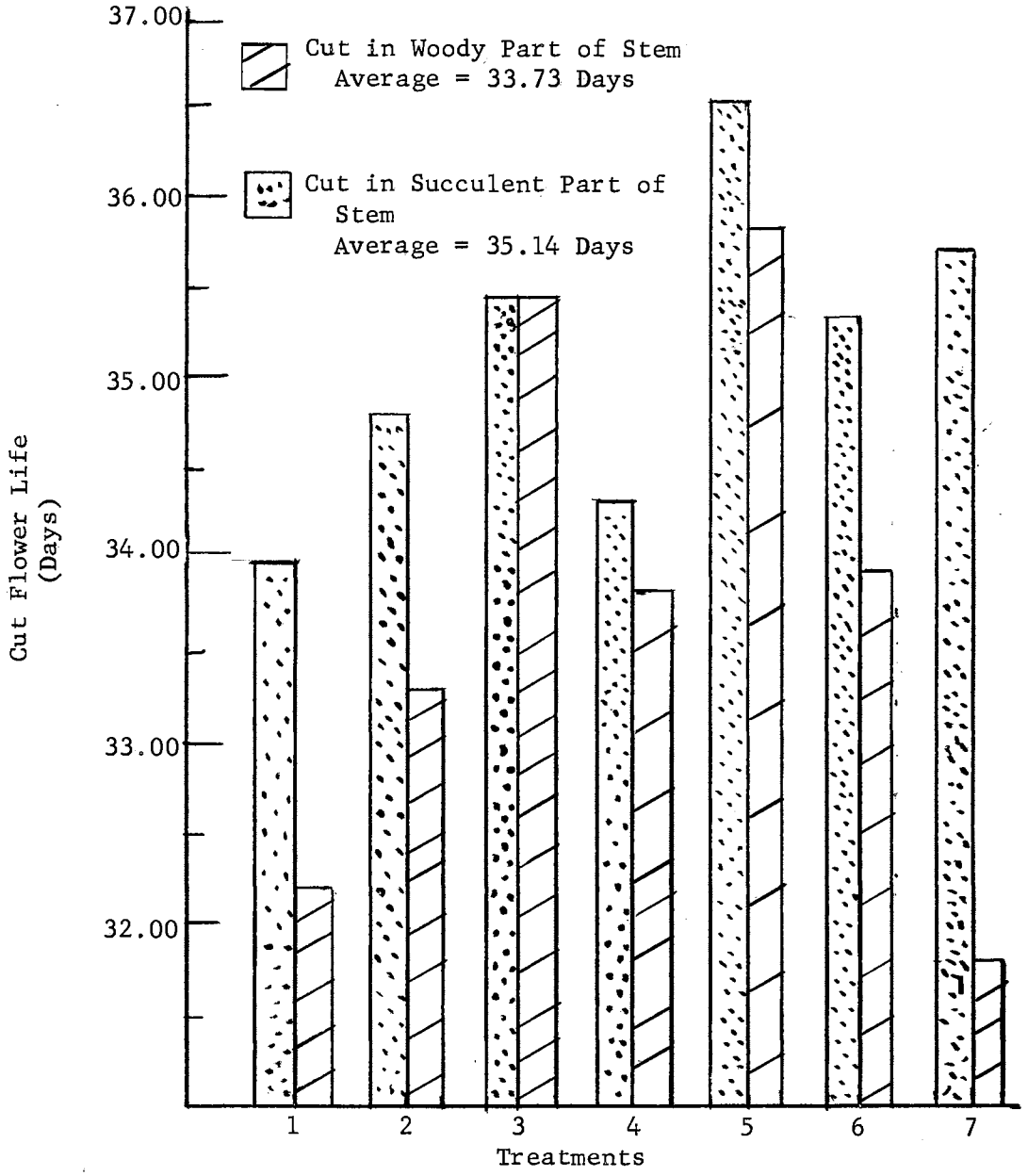



Figure 20. The Effect of Certain Stem Cutting Treatments* in the Woody and Succulent Part of the Stem on Cut Flower Life of Chrysanthemum Flowers

*See page 30 for explanation of treatments.

For stems cut in the woody part the best treatment again was the horizontal cut with a mean cut flower life of 35.75 days followed by the treatment snapping the stem with 35.50 days. The next to the lowest treatment for cut flower life was the slant cut with the stem crushed one inch with 32.17 days while the lowest was the cut made with shears with 31.84 days. The difference between the highest and lowest treatment in the woody part of the stem was 10.91 per cent.

The mean for cut flower life for all the treatments involving the succulent part of the stem was 35.14 days. All of the treatments involving the woody part of the stem had a mean of 33.73 days. Cutting the stem in the woody part caused a 4.01 per cent decrease in cut flower life.

## Experiment VIII

Table XXXIX shows the combined effects of all cultivar on days to open and cut flower life, while Figure 21 shows the cultivar effect on days to open and Figure 22 shows the cultivar effect on cut flower life using different flower bud opening solutions.

The flower buds in Everbloom required 10.75 days to open and in 8-hydroxyquinoline citrate (8-HQC) plus sucrose, 10.83 days. In Petalife the flower buds required 12.33 days to open but did not open properly. After one week in F. M. Budmagic the leaves began to develop lesion and dry up. With water the flowers required 23.50 days to open and the flowers had a more flattened appearance and the ray florets were very narrow. The foliage on flowers in the water solution was excellent.

TABLE XXXIX

THE EFFECT OF FLOWER BUD OPENING SOLUTIONS ON DAYS TO OPEN AND CUT FLOWER LIFE

| Flower Bud Opening Solutions | Days to Open | Cut Flower Life |
|---|---|---|
| Everbloom | 10.75 | 21.04 |
| 200 ppm 8-Hydroxyquinoline Citrate Plus 2% Sucrose | 10.83 | 28.75 |
| Petalife | 12.33 | 21.21 |
| F. M. Budmagic | 25.34 | 1.00 |
| Water | 23.50 | 4.96 |

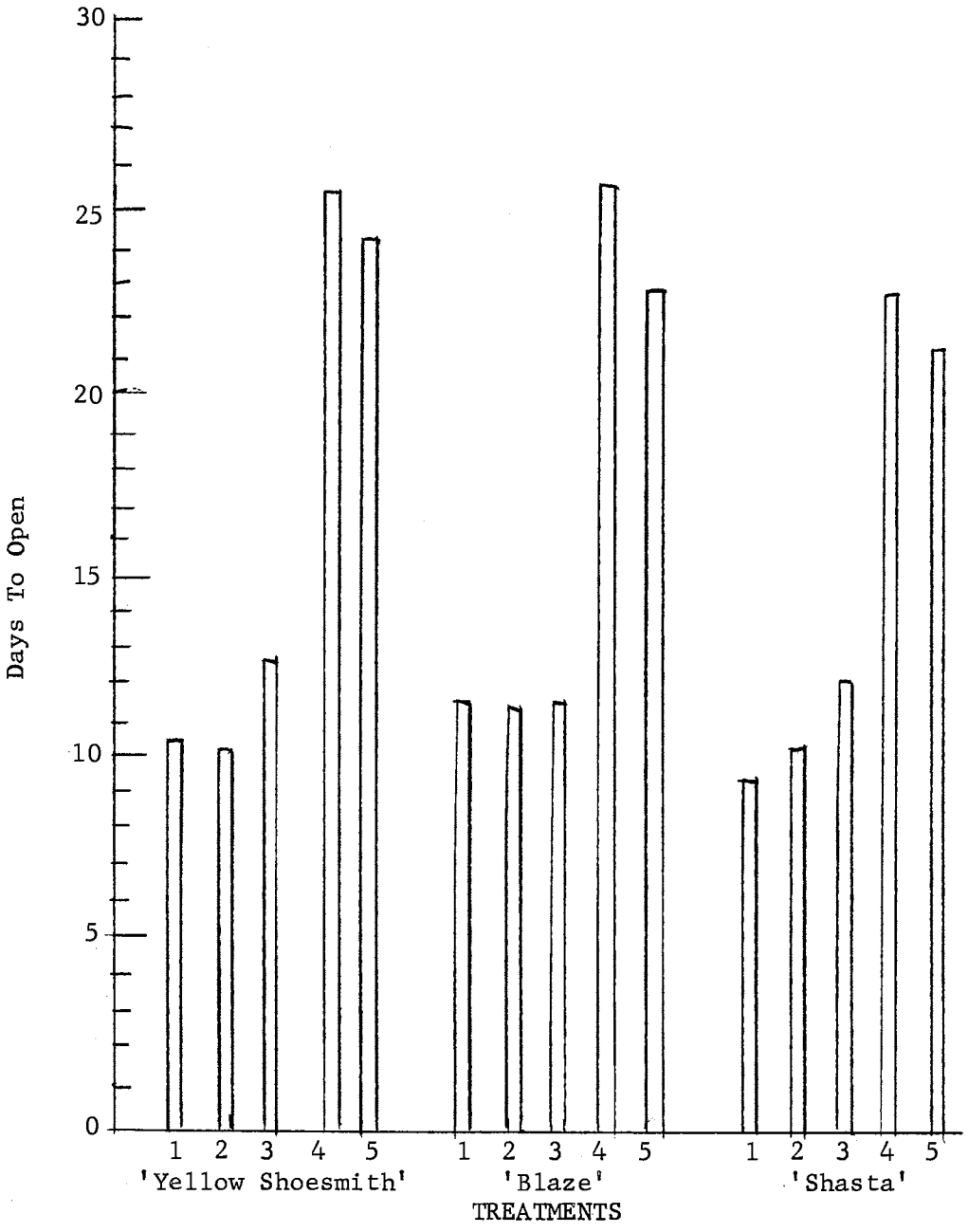



Figure 21. The Effect on Days to Open of Various Solutions* on the Opening of Flower Buds of Three Cultivars of Chrysanthemums

*See page 32 for explanation of various solutions.

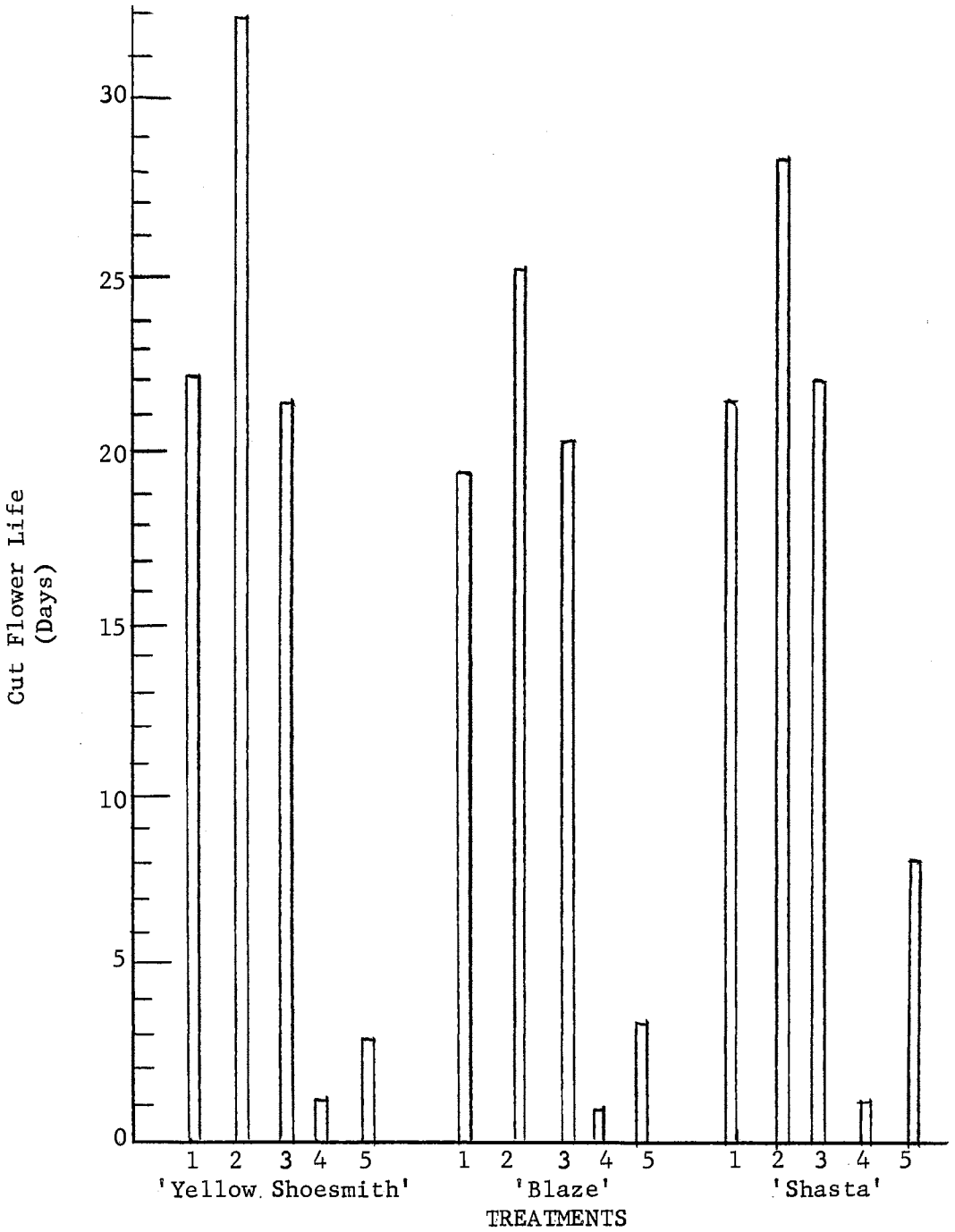



Figure 22. The Effect on Cut Flower Life of Various Solutions* on the Opening of Flower Buds of Three Cultivars of Chrysanthemums

*See page 32 for explanation of various solutions.

Flowers in a solution of 8-HQC plus sucrose had a mean cut flower life of 28.75 days, while those in either Everbloom or Petalife solution showed an approximate decrease of 26 per cent in cut flower life. Flowers in F. M. Budmagic had a cut flower life of only 1.00 day, while those in the water solution had a cut flower life of 4.96 days.

Flowers of 'Yellow Shoesmith' and 'Blaze' in a solution of Petalife were lighter in color. This was also true for flowers in water. When opened in 8-HQC plus sucrose, 'Yellow Shoesmith' developed an intense yellow color.

## Experiment IX

The effects of the different concentrations of floral preservatives on cut flower life are shown in Figure 23. The best concentrations for the different treatments according to cut flower life are given below:

(1) twice the recommended rate of Petalife = 35.88 days

(2) 200 ppm 8-hydroxyquinoline citrate, 300 ppm Alar plus 4% sucrose = 35.38 days

(3) one-half the recommended rate of Everbloom = 35.13 days

(4) 200 ppm 8-hydroxyquinoline citrate (8-HQC) plus 2% sucrose = 35.00 days

(5) the recommended rate of F. M. Super = 30.50 days

(6) water = 29.50 days

(7) one-half the recommended rate of F. M. Regular = 25.88 days

(8) one-half the recommended rate of F. M. Budmagic = 24.00 days.

The most effective floral preservatives and concentrations in relationship to cut flower life were: (1) twice the recommended rate of Petalife, (2) 200 ppm 8-HQC, 300 ppm Alar plus 4% sucrose, (3) one-half

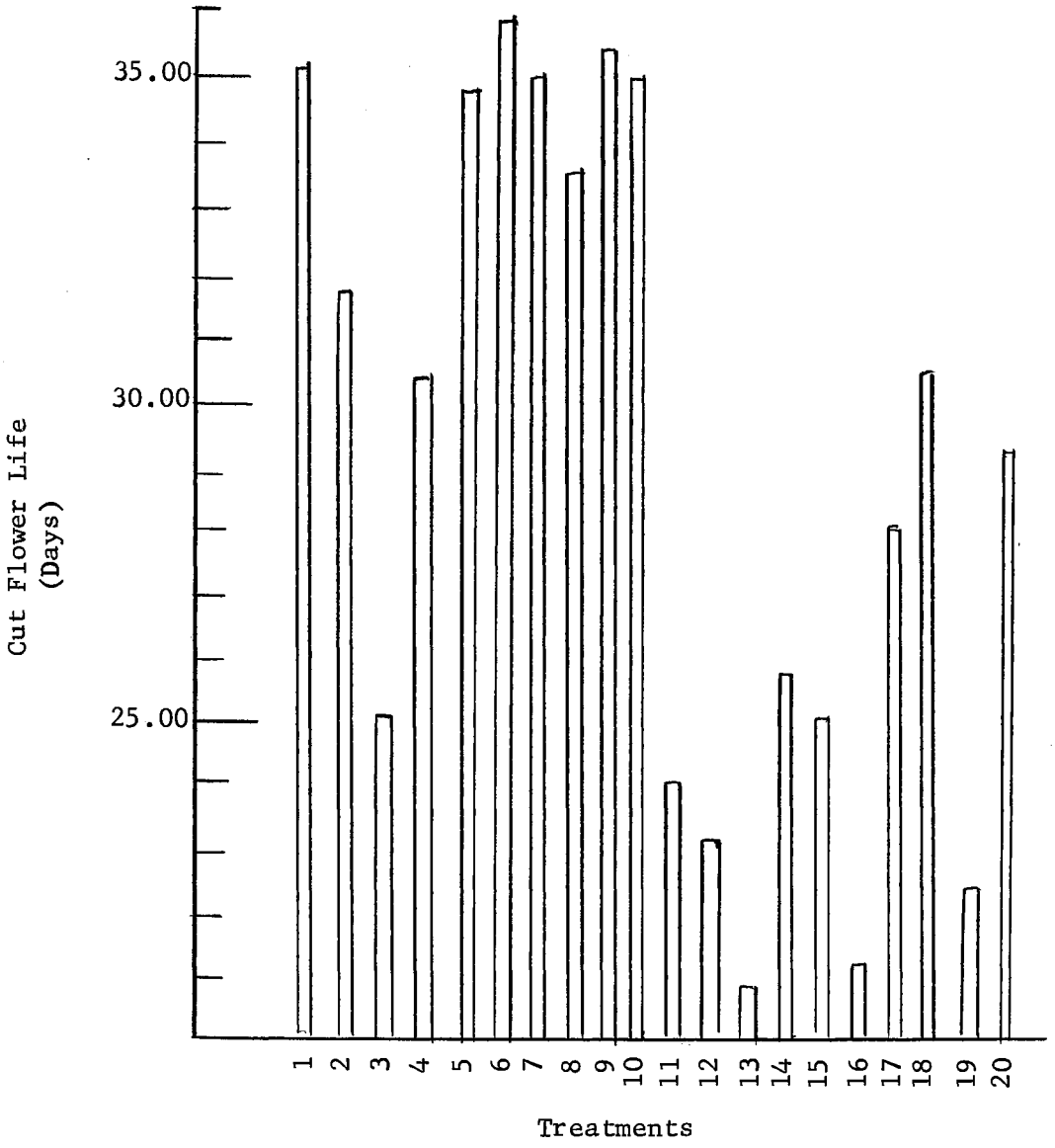



Figure 23. The Effect of Using Different Floral Preservatives* on Chrysanthemum Cut Flower Life

*See page 108 for explanation of different floral preservative treatments.

the recommended rate of Everbloom, and (4) 200 ppm 8-HQC plus 2% sucrose. All of these treatments produced a cut flower life of 35 days or more. The preservative with the lowest cut flower life was twice the recommended rate of F. M. Budmagic with a mean of 21.00 days.

Flower diameters from the different concentrations of floral preservatives are shown in Figure 24. The largest average flower diameters under the different treatments are given below:

(1) 100 ppm 8-hydroxyquinoline citrate, 200 ppm Alar plus 4% sucrose = 130.32 mm.

(2) twice the recommended rate of Petalife = 128.75 mm.

(3) 200 ppm 8-hydroxyquinoline citrate plus 2% sucrose = 128.13 mm.

(4) recommended rate of Everbloom = 125.94 mm.

(5) recommended rate of F. M. Super = 120.00 mm.

(6) water = 114.69 mm.

(7) recommended rate of F. M. Budmagic = 114.69 mm.

(8) one-half recommended rate of F. M. Regular = 114.07 mm.

The most effective floral preservative and concentration in relation to flower diameter was 100 ppm 8-hydroxyquinoline citrate, 200 ppm Alar plus 4% sucrose with a mean of 130.32 millimeters followed by 400 ppm 8-hydroxyquinoline citrate, 500 ppm Alar plus 4% sucrose which had a mean of 129.38 millimeters. The smallest flower diameter mean was 107.51 mm. from the treatment of twice the recommended rate of F. M. Regular.

As discussed earlier in this paper, a pH range from 3 to 5 is best for cut flower life. Six of the treatments were found to be in this range. They were:

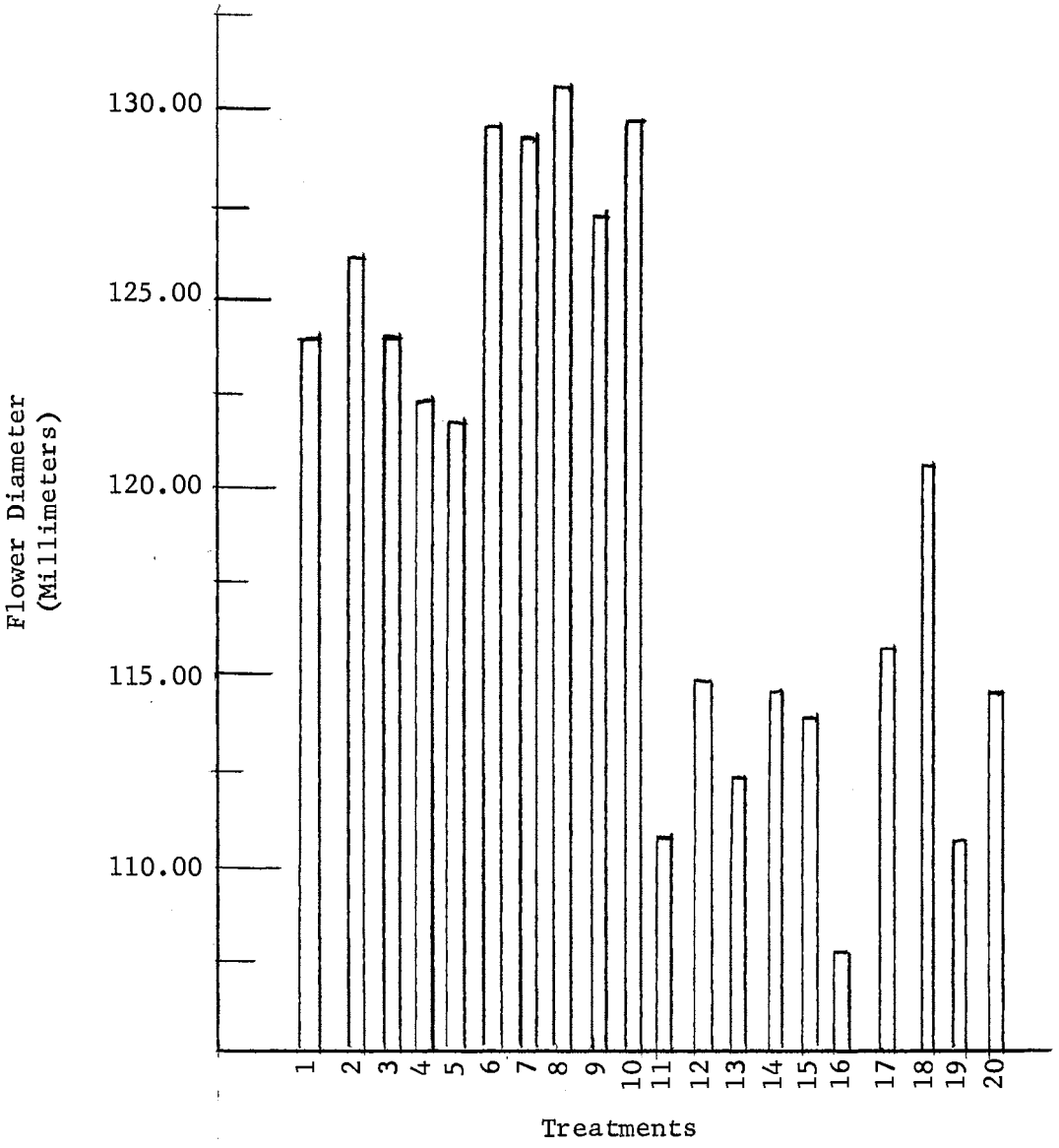



Figure 24. The Effect of Using Different Floral Preservatives* on Chrysanthemum Flower Diameter

*See page 108 for explanation of different floral preservative treatments.

(1) twice the recommended rate of Everbloom, 4.7 pH

(2) one-half the recommended rate of Petalife, 4.8 pH.

(3) the recommended rate of Petalife, 4.4 pH.

(4) twice the recommended rate of Petalife, 3.5 pH.

(5) 400 ppm 8-hydroxyquinoline citrate, 500 ppm Alar plus 4% sucrose, 4.6 pH.

(6) one-half the recommended rate of F. M. Super, 4.9 pH.

The mean cut flower life of these six treatments was 31.65 days. The other fourteen treatments had a pH above 5.0. Their mean cut flower life was 28.17 days, a decrease of 11.00 per cent from the treatments with a pH below 5.0. The measurements for pH of all the solutions are shown in Figure 25.

Below are several visual symptom observations on chrysanthemums resulting from use of the different floral preservative treatments:

(1) one-half the recommended rate of Everbloom--good foliage, 'Yellow Shoesmith' pale color.

(2) the recommended rate of Everbloom--damaged foliage.

(3) twice the recommended rate of Everbloom--damaged foliage.

(4) one-half the recommended rate of Petalife--good foliage, white center with 'Pink Indianapolis', 'Yellow Shoesmith' pale color.

(5) the recommended rate of Petalife--good foliage, white center with 'Pink Indianapolis', 'Yellow Shoesmith' pale color.

(6) twice the recommended rate of Petalife--slightly yellow foliage, white center with 'Pink Indianapolis', 'Yellow Shoesmith' pale color.

(7) 200 ppm 8-hydroxyquinoline citrate plus 2% sucrose--good foliage, 'Yellow Shoesmith' bright color.

(8) 100 ppm 8-hydroxyquinoline citrate, 200 ppm Alar plus 4% sucrose--slightly yellow foliage, 'Yellow Shoesmith' bright color.

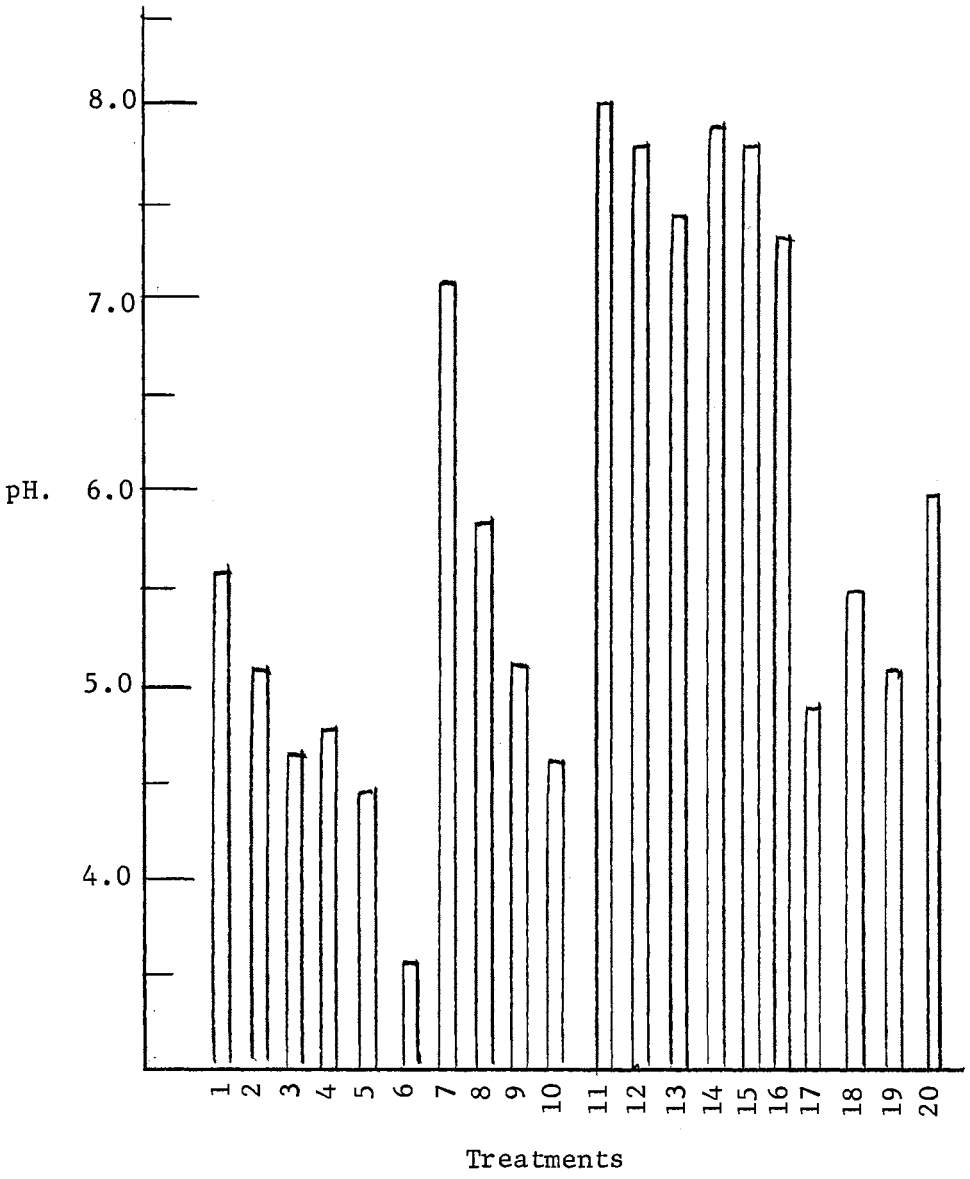



Figure 25. The pH of Different Floral Preservatives*

*See page 108 for explanation of different floral preservative treatments.

(9) 200 ppm 8-hydroxyquinoline citrate, 300 ppm Alar plus 4% sucrose--yellow foliage, brown center with 'Pink Indianapolis', 'Yellow Shoesmith' bright color.

(10) 400 ppm 8-hydroxyquinoline citrate, 500 ppm Alar plus 4% sucrose--yellow and damaged foliage, 'Blaze' pale color, 'Pink Indianapolis' brown center, 'Yellow Shoesmith' bright color.

(11) one-half the recommended rate of F. M. Budmagic--burned foliage.

(12) the recommended rate of F. M. Budmagic--burned foliage.

(13) twice the recommended rate of F. M. Budmagic--burned foliage, 'Blaze' pale color.

(14) one-half the recommended rate of F. M. Regular--burned foliage.

(15) the recommended rate of F. M. Regular--burned foliage.

(16) twice the recommended rate of F. M. Regular--burned foliage, 'Blaze' pale color.

(17) one-half the recommended rate of F. M. Super--burned foliage, 'Yellow Shoesmith' pale color.

(18) the recommended rate of F. M. Super--burned foliage, 'Pink Indianapolis' white center.

(19) twice the recommended rate of F. M. Super--burned foliage.

(20) water--good foliage.

## Experiment X

Long-term storage of chrysanthemum flower buds for up to four weeks at -0.56 degrees centigrade had no influence on number of days required to open for flowers cut in stage one of flower development but at 4.44 degrees centigrade the number of days to open decreased as storage time increased. This is shown in Figure 26. It should be emphasized that the results in Figure 26 are over-all means of two cultivars, 'Blaze' and 'Shasta'.

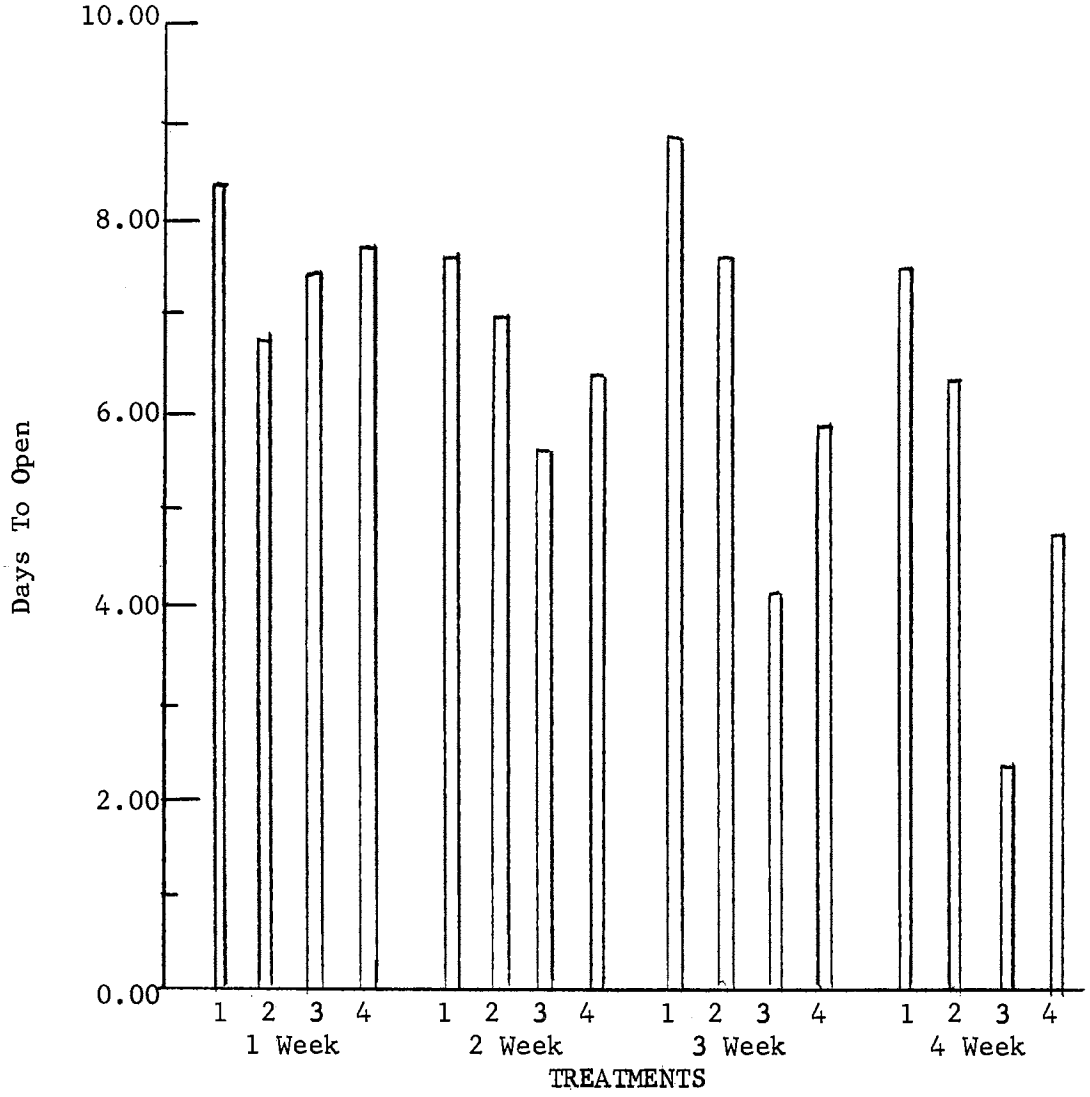



Figure 26. The Effect of Storage Treatments* on Days to Open for Chrysanthemum Flowers Cut in Stage One of Flower Development

*See page 33 for explanation of the different storage treatments.

The effect of storage time and treatment on cut flower life is shown in Figure 27. The flower buds that were stored either one week or three weeks had approximately the same cut flower life. Flower buds stored two weeks had an actual increase of five days in their cut flower life. With the fourth week of storage there was an approximate decrease of three days in cut flower life. Comparing the four treatments during the four-week storage period, the cut flower life was approximately the same except for treatment four.

Flower diameter size, Figure 28, increased slightly as time of storage increased. None of the chrysanthemum leaves were wilted after the first week of storage. Starting the second week of storage the flower buds stored dry at -0.56 degrees centigrade and stored in wet newspaper at 4.44 degrees centigrade had wilted leaves when taken from storage. The treatment that had the least amount of deterioration of the leaves was the one that was stored with the base of the stems in "Oasis" at -0.56 degrees centigrade. Flower buds that were stored for four weeks at 4.44 degrees centigrade in wet newspaper developed into flowers that were flat and with narrow ray florets.

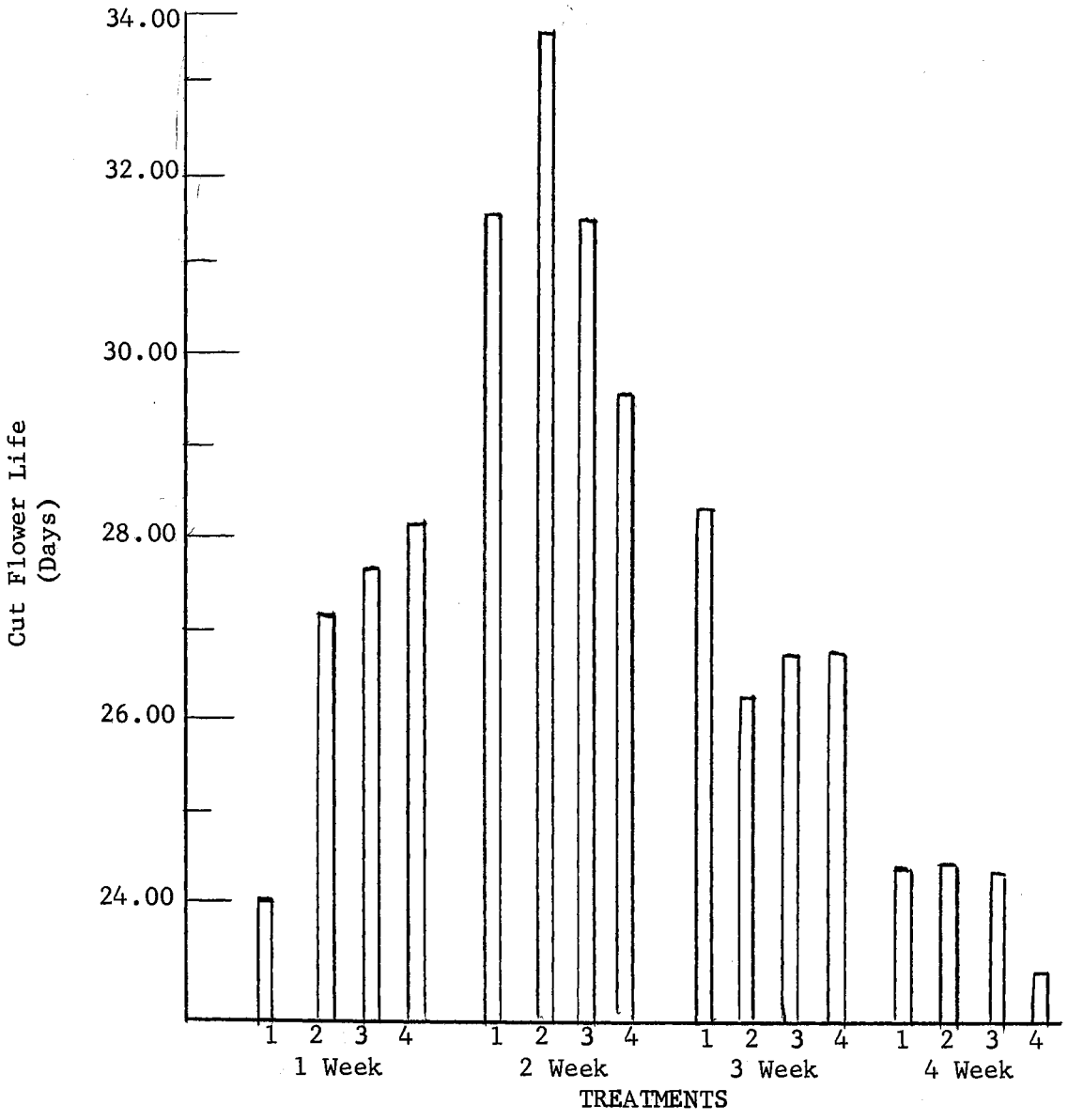



Figure 27. The Effect of Storage Treatments* on Cut Flower Life of Chrysanthemum Flowers Cut in Stage One of Flower Development

*See page 33 for explanation of the different storage treatments.

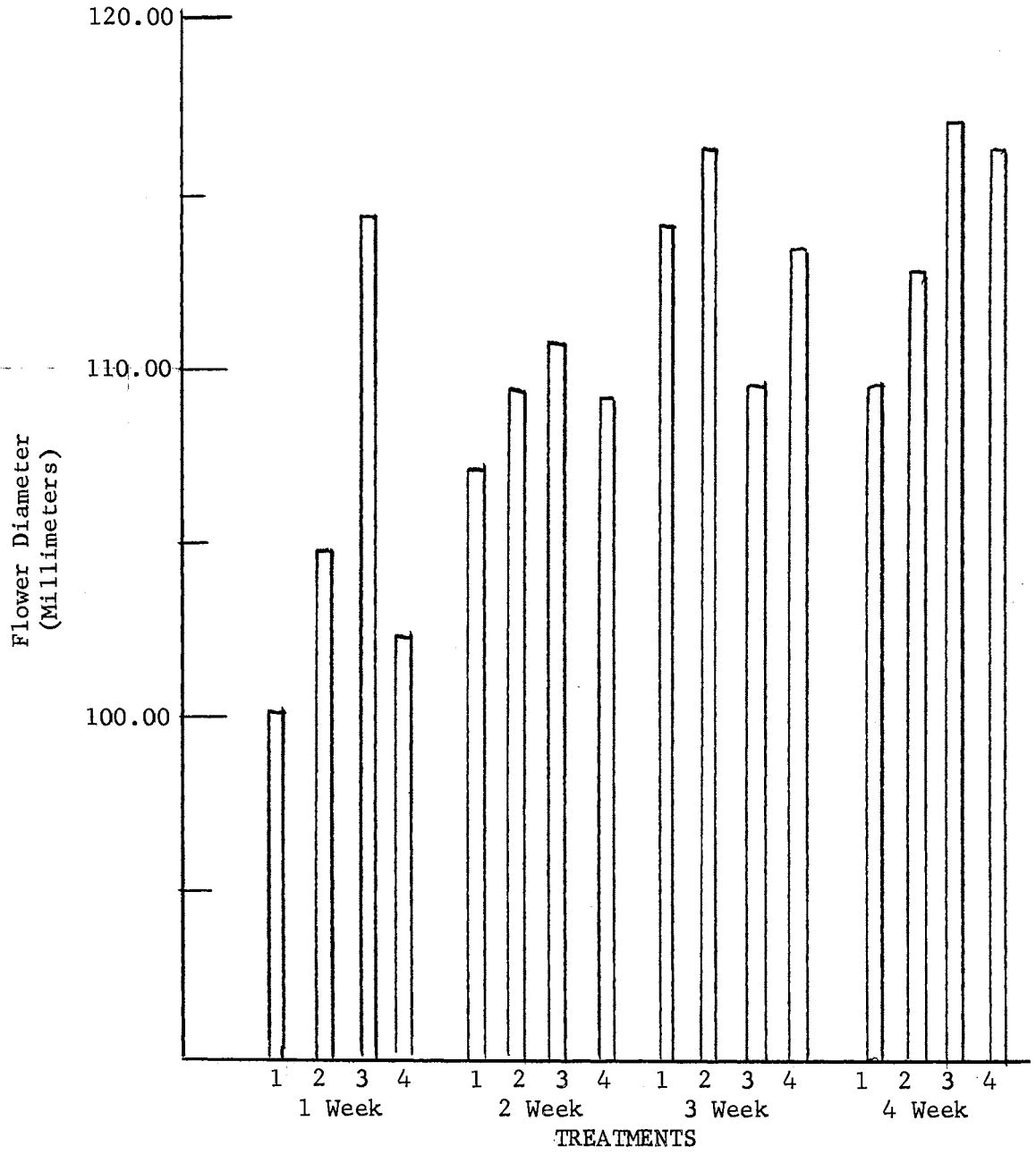



Figure 28. The Effect of Storage Treatments* on Flower Diameter of Chrysanthemum Flowers Cut in Stage One of Flower Development

*See page 33 for explanation of the different storage treatments.

# CHAPTER V

## DISCUSSION AND CONCLUSIONS

Chrysanthemum flowers are normally harvested when they have opened on the plant. By harvesting chrysanthemums in the bud stage, a grower would have more flexibility in both his cultural and marketing practices.

The main purpose of this study was to determine which of the five light intensity treatments would be best for opening chrysanthemum flower buds off the plant. The results from the four light intensity experiments showed that varying light intensity from 50 to 800 foot-candles had no significant effect on the number of days required for flowers cut in the bud stage to open, the cut flower life, or the open flower diameter. One reason that light intensity was not significant for any of the experiments was due to the fact that the degrees of freedom to make the F-test were only one and to have a significant effect the differences between the two light intensities would have to be extremely large.

Bud stage at cutting was significant for the number of days required for flowers cut in the bud stage to open in all four light intensity experiments. This work with the two bud stages showed that buds in either stage one or stage two of flower development could be opened satisfactorily off the plant. Stage one, however, took approximately twice the number of days for the flower buds to open as compared

to stage two. In the first two light intensity experiments, bud stage at cutting was significant for cut flower life, but was not significant in the last two light intensity experiments. These results of the first two light intensity experiments showed that flowers from stage two flower development lasted longer than the flowers from stage one. In the higher light intensity experiments, it appeared that the stage of flower development at cutting had no influence on the cut flower life. Flower diameter as influenced by the two stages of flower bud development was not tested for significance. It appeared from the data on flower diameter that cutting the chrysanthemum flowers earlier (at stage one) caused the open flower diameter to be smaller than if the flowers were cut at stage two of flower bud development. Flowers cut in stage one, however, were of satisfactory size for the commercial market.

The results from all four light intensity experiments showed that cultivar was significant for the number of days required for flowers cut in the bud stage to open, cut flower life and open flower diameter. This significance shows the necessity to conduct specific cultivar trials before the practice of cutting chrysanthemums in the bud stage can be applied commercially.

Trial was significant for cut flower life in all four of the light intensity experiments. In the first experiment, the cut flower life probably was reduced in the second replication (trial) because of an overdose of iron chelate mistakenly applied during the culture of the crop in the greenhouse. Chrysanthemum flowers in the first replication of the second light intensity experiment wilted more than usual for an unknown reason and cut flower life was more difficult to determine.

In the third and fourth light intensity experiments, cut flower life probably was reduced in the first replication by a slight infestation of red spider mites.

The chrysanthemum flowers that were opened in the four light intensity experiments (stage one and stage two) had shorter cut flower life and smaller flower diameter than the chrysanthemum flowers that were opened on the plant (Table XXXVIII). Results in this same table compare off-the-plant opening in the greenhouse vs. on-the-plant opening in the greenhouse. The data from this table show that the environment in the greenhouse was better than the controlled environment in the growth chambers relative to cut flower life and flower diameter. It appears that the Cool-White fluorescent lamps were probably not optimum for plant growth responses. A Wide Spectrum Gro-Lux fluorescent lamp would possibly have given more favorable results for the light intensity experiments.

Since chrysanthemum flower buds are still growing and developing after having been cut, an adequate supply of water is necessary for bud expansion and stem elongation. This is why the best cut should be found for cutting the stems of the chrysanthemum flower buds. In the first experiment all cuts were made in the succulent part of the stem. The best treatments were a slant cut with stem crushed one inch, a slant cut, and a horizontal cut. A second experiment was conducted to determine the best treatment in the woody part of the stem and also in the succulent part of the stem, and then compare the results. The results showed that a horizontal cut was the best treatment for both the succulent and woody part of the stem. These results tend to substantiate the claim that a clean cut reduces the bacterial and

fungal growth as compared to snapping or breaking the stem. Also, cutting the stem in the woody part caused a 4.01% decrease in cut flower life as compared to cutting in the succulent part of the stem. This suggests that if chrysanthemum flowers are harvested as buds, the stems should be cut in the succulent area.

The results from the flower bud opening solutions experiment showed that chrysanthemum flower buds in Petalife, F. M. Budmagic, and water did not open properly and were not commercially acceptable. Flower buds did open properly in both Everbloom and 200 ppm 8-HQC plus 2% sucrose and were commercially acceptable. Possibly different concentrations of these solutions would improve the quality of the chrysanthemums that are opened off the plant.

Once the chrysanthemum flower buds have been opened, every practical means of extending their useful life should be employed. A floral preservative is one means that can be used to extend the vase-life of various flowers. An experiment was conducted to find the optimum floral preservative for chrysanthemum flowers, and the proper concentration. The results from the treatments F. M. Budmagic, F. M. Regular, and F. M. Super should be disregarded since the leaves developed lesions and dried within one or two weeks, even at one-half the recommended concentration. The concentrations and treatments were evaluated according to cut flower life, flower diameter, and comments about the over-all appearance of the foliage and flower. Some recommended concentrations based on the above evaluation are:

(1) one-half the recommended concentration of Everbloom

(2) 200 ppm 8-HQC plus 2% sucrose

(3) 100 ppm 8-HQC, 200 ppm Alar plus 4% sucrose.

The pH of these solutions were above 5.0 which tends to disagree with the recommendation that the pH of floral preservatives should be between 3.0 to 5.0. Future studies should be conducted to determine if pH is important for the cut flower life of chrysanthemum flowers.

Long-term storage appears to be adaptable to chrysanthemum flower buds. Chrysanthemum flower buds opened satisfactorily after four weeks in storage. Storage of four weeks did cause a decrease in cut flower life. All treatments were satisfactory for long-term storage excluding the storage treatment at 4.44 degrees centigrade with the base of stems wrapped in wet newspaper and placed in plastic film, folded and stapled every six inches. These storage methods would allow a grower or wholesaler to store the flower buds for peak demand or until the marketing conditions become more favorable.

It appears that chrysanthemum flower buds can be successfully opened off the plant. All of the factors that relate to opening and shipping chrysanthemum flower buds need to be studied further in order for this method to be practically applied. It could be of real economic importance to the grower, the wholesaler, the florist, and the ultimate consumer.

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# VITA

Jack Charles Kurt

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF LIGHT INTENSITY, FLORAL PRESERVATIVE SOLUTIONS, AND VARIOUS HANDLING METHODS ON FLOWER BUD OPENING AND KEEPING QUALITY OF CUT CHRYSANTHEMUMS

Major Field: Horticulture

Biographical:

Personal Data: Born in Bartlesville, Oklahoma, January 4, 1947, the son of Mr. and Mrs. Robert C. Kurt.

Education: Graduated from College High School, Bartlesville, Oklahoma in 1965; attended Oklahoma State University in 1965; attended the University of Florida in 1966; received the Bachelor of Science degree from Oklahoma State University in 1969 with a major in Horticulture; completed requirements for a Master of Science degree in Horticulture in May, 1971.

Professional Experience: Graduate Research Assistant, Horticulture Department, Oklahoma State University, 1969-1970.