T H E S I S

SOME EFFECTS OF TEMPERATURE ON CARNATION CALYX SPLITTING

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY DAVID LAWRENCE WAGNER

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Chapter I

INTRODUCTION

Splitting of the carnation calyx is one of the more serious troubles encountered by the carnation grower. In calyx splitting (Fig. 1.), two adjoining sepals of the calyx tube separate, allowing the petals to bend down. Thorpe in the 1880's developed a carnation which he stated was the beginning of the non-splitting race (1). Since that time many attempts have been made to determine the cause of calyx splitting but the opinions and experimental results are somewhat contradictory.

The value of carnation flowers produced under glass, in the United States, according to the United States Census of 1950, was approximately 20 million dollars. Normally 10 per cent of the flowers will split. If sold, split carnations command less than half the price of normal carnations. Therefore carnation growers of the United States are losing over one million dollars per annum as a result of calyx splitting.

Splitting has been attributed to many factors, a few of which are: heredity, fertilizers, mineral nutrition, temperature, light, water, soil, and disease. Splitting usually occurs in all the greenhouse ranges of the Denver,

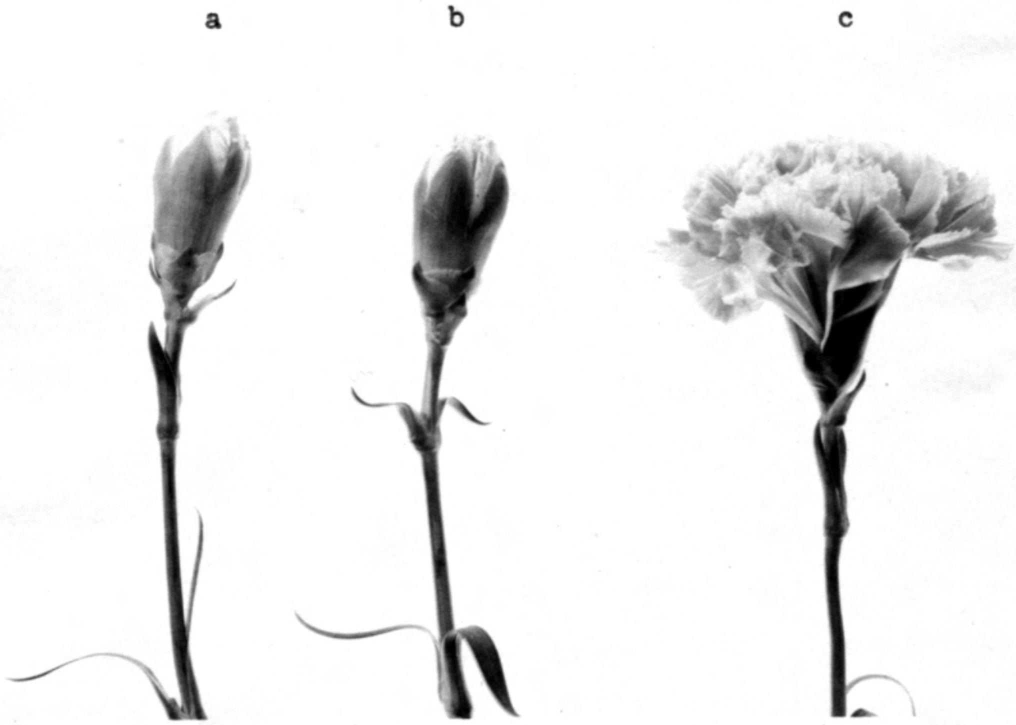

Fig. 1. Carnation buds showing (a) normal bud, (b) partially split bud, and (c) fully split bud.

Colorado, area at approximately the same time. However, all the factors blamed for causing splitting do not occur in all the greenhouses at the same time. Some factor or factors common to all greenhouses must be the major cause of splitting. Outside temperatures and light intensities appear to be factors which are common to all greenhouse ranges. Temperatures within most greenhouses will flucuate as the outside temperatures and light intensities vary.

The problem

What are the effects of temperature on carnation calyx splitting?

Problem analysis.--Before answering the major question, it is necessary to answer the following:

1. What time or times of the year does the greatest amount of carnation calyx splitting occur?
2. In what bud stage or stages does the carnation calyx split?
3. What effect does low night temperatures have on carnation calyx splitting?
4. What effects do constant and variable day temperature have on carnation calyx splitting?

Delimitation.--This investigation will be limited to the carnation variety White Patrician and its sport Frosted Pink Patrician and their responses to temperature. The study will be limited further by the facilities available for temperature investigations at the Colorado Agricultural Experiment Station Floriculture Research Greenhouses. Wherever possible interrelated factors will be investigated simultaneously with temperature.

Definition of terms.—Splitting or splits refers to the separation of two adjoining sepals so that the petals, deprived of their support, bend down.

Low night temperature, as used here, means 40°F.

Low day temperature, as used here, means 50°F.

Low light intensity, refers to approximately 500 foot candles.

Chapter II

REVIEW OF LITERATURE

The double perpetual-flowering carnation originated in France and has been improved by American growers. The carnation was first introduced to the United States in 1852 (1).

Splitting a hereditary factor:--In the early 1880's Thorpe stated that he had developed a non-splitting race of carnations (1). At the beginning of the twentieth century, Ward (28) and Dorner (16) assumed splitting to be entirely hereditary. Connors (11) assumed splitting of the carnation calyx to be affected by both hereditary and environmental factors, while Stuart (26) stated that splitting was due to the formation of adventitious buds in the flower rather than to inherent weakness of the calyx.

Carnation flower form, as stated by Norton (20, 21), Batchelor (2), and Stuart (26), follows Mendel's law of dominance. The single is pure recessive, the super-double or the almost-always-splitting bullhead is an incomplete dominant, and the standard or commercial double is a heterozygote.

Ward (28) reported that in selecting a seedling for future trial, good firm calyces should be selected to avoid splitting. The selection of cuttings for propagation from non-splitting plants was found by Weinard (29,30,31) to reduce the occurrence of splitting.

Temperature relations:--Scott (24) stated in 1899 that allowing the greenhouse temperature to go as low as 40° F or less on occasional nights would cause splitting. Dick (15) in 1915 wrote that rapid fluctuations in greenhouse day temperatures will cause splitting. Later, other investigators (36,26,3,23,27) reported that splitting could be traced to unfavorable temperatures.

Szendel (27) has done more work on the relation of temperature to carnation calyx splitting than any other investigator. He found that lower temperatures produced a higher percentage of splits, and that short periods of low temperatures occurring twice a month caused significantly more splitting than frequent low temperature periods.

Prolonged periods of extremely low temperature increased significantly the average number of petals, however, the correlation between number of petals and percentage of splits was not significant. Szendel concluded that the importance of the number of petals to splitting is of relative value only.

Light intensity:--Connors (11) reported that dull dark weather and lack of light at certain stages in the development of the bud become active factors in the matter of splitting. Allwood (1) and Weston (35) believed that lack of sunshine was a major cause of splitting. Allwood further stated that splitting caused by lack of sunshine could be counteracted by cool temperatures and ventilation.

Fertilizer and mineral nutrition:—Baur (3) stated that splitting of the calyx may be traced to overdoses of fertilizers. Szendel (27) found that frequent applications of complete nutrient solution increased splitting. However, several other investigators (17,22,34,32) have reported no consistent relationship between fertilizer treatments and the occurrence of split calyces.

Time of applying large amounts of fertilizer chemicals had no effect on splitting, according to Pember and Adams (22). They stated that high nitrogen reduced splitting. Beach (5,7) found that high nitrogen produced less splitting, and stated that fluctuation of the nitrate level, rather than the level itself, seemed best to account for the large number of splits on low nitrogen plots. Holley et al., (19) found different nitrate levels produced no significant difference within the split grade. High nitrogen was reported by Post (23), and Clapp and Folley (10) to cause increased splitting.

Connors (12), and Biekart (8) investigating the relationship of nitrogen and carbohydrates, found the tendency to split was accentuated by high carbohydrates and low nitrogen, while high nitrogen and low carbohydrates reduced splitting.

Szendel (27), and Clapp and Folley (10) reported that excess phosphorus increased splitting, whereas, deficient phosphorus and potassium decreased splitting. Beach (4) reported that 3 levels of phosphorus had no significant effect on calyx splitting.

According to Post (23) and Clapp and Folley (10), high potassium yielded less splits than low potassium. Szendel (27) reported that increasing the amount of potassium available to plants had no significant effect on splitting. Beach (7) stated that high potassium with high nitrogen reduced splitting.

Water relations:--Differences in soil moisture, according to Pember and Adams (22), Beach (4), and Post (23), had no influence on splitting. However, Holley et al., (19) found that high moisture gave significantly more splits than low moisture.

Soil medium:--Connors (13,14) and Biekart and Connors (9) stated that sand produced less splits than soil; whereas, Szendel (27) reported higher percentages of splits with sand than with soil treatments. Several soil mixtures used by Connors (11) produced no difference in percentage of splits.

Szendel (27) stated that the addition of peatmoss to sand or soil had no effect on splitting. Old soil produced less splits than new soil in experiments by Weinard and Decker (33).

Wheeler and Adams (36) reported that it appeared probable that the character of the manure effects the percentage of splitting. Gunesch (18) found that pasturization and incorporation of manure into soils did not effect yield of splits.

No definite effect upon splitting can be ascribed to the type of bench construction (11) or time of benching (11), steaming of soil (33), liming of soil (22,33), mulchings (19) and the addition of sodium selenate (6,22).

Stuart (26) assumed that regardless of the cause of splitting, it occurs at an early stage in the development of the flower. Connors (11) and Szendel (28) reported that the stage of bud development most susceptible to splitting is at the time the bud is opening and exposing the petals.

Chapter III

METHODS AND MATERIALS

The problem of carnation calyx splitting is one of varied interest. In this investigation the problem is limited to the effects of temperature on calyx splitting. The carnation varieties White Patrician and Frosted Pink Patrician were selected for test plants because they are commercial varieties that have the fault of producing a high percentage of split calyces during some periods of the year.

General methods and materials:--All studies were carried on in the Colorado Agricultural Experiment Station Greenhouses at Fort Collins, Colorado, except for records from the Ralph Hill Greenhouses, Denver, Colorado, which were used in one study.

Plants used at the experimental greenhouses were propagated from disease-free, indexed mother blocks, and planted in a good sandy loam soil, either in benches or pots. All plants grown in pots were planted directly into the pots from the propagating sand. Potted plants were used in all experiments where plants were moved into temperature chambers.

Nutrient levels were maintained at 25 to 50 ppm nitrogen, 2 to 5 ppm phosphorus, and 25 to 50 ppm potassium (Spurway tests). All nutrients were applied in liquid form for accuracy and ease of feeding all pots alike.

A minimum night temperature of 50° F was maintained at all times except when plants were in chambers for temperature treatment. The day temperature fluctuated according to the weather conditions. On sunny days the temperature usually ranged from 60 to 70° F, while on cloudy days the temperature usually remained slightly below 60° F during winter months.

Two different types of cool temperature chambers were used. The first year a lean-to chamber made of hotbed sash was constructed on the outside of the greenhouse. This chamber was 4 feet wide, 7 feet long, and 4.5 feet high. Two 60-foot electric heating cables, fastened on the sides, supplied the heat to maintain a minimum night temperature of 40° F.

The second year 2 walk-in refrigerators served as the temperature chambers. These refrigerators were 4 feet wide, 5 feet long, and 7 feet high. They were equipped with lights so that plants could be left in them for long periods of time. These lights consisted of 2 4-foot 40 watt daylight type flourescent tubes, placed 3 feet above the floor, on opposite walls, and two 200 watt incandescent bulbs, with reflectors, placed in the center of the chamber 5 feet above the floor. These lights produced a light intensity in the refrigerators of from 100 foot candles at floor level to 500 foot candles 4 feet above the floor. Higher light intensities were tried but were unsatisfactory since the refrigerator cooling units could not disperse the added heat. The lights were electrically controlled to produce a 9-hour day.

All plants were moved in and out of the cool temperature chambers when the carnation house temperature was near 50° F, except when rapid temperature changes were under study.

Time of calyx splitting:—To determine the time of the year when the largest amount of calyx splitting occurred, daily production and quality records for the variety White Patrician were examined. Records kept by the Ralph Hill Greenhouses, Denver, Colorado, and the Colorado Agricultural Experiment Station Greenhouses for the years 1948 to 1951 and 1949 to 1951 respectively were analyzed.

Stage of bud at time of calyx splitting:—To find the stage of bud development when the calyx splits the following records were kept on 443 buds; the date the calyx began opening, the date the calyx split, and the date the flowers were out.

EFFECT OF LOW NIGHT TEMPERATURE

Experiments were set up to determine the effect of low night temperatures on carnation calyx splitting. Plants were moved from the carnation house to a chamber where the minimum night temperature was 40° F.

Experiment 1:--Sixty plants of the variety Frosted Pink Patrician, growing in 6-inch pots, were pinched on September 29, 1950. These plants were given 40° F minimum night temperature treatments for 1, 3, and 7 consecutive nights at bud stages of 10, 14, and 18 weeks after pinching, or a total of 9 different treatments. Each treatment consisted of 6 plants. Six check plants remained in the carnation house at a minimum night temperature of 50° F.

Experiment 2:--One hundred and ninety-two plants of the variety Frosted Pink Patrician, growing in 6-inch pots, were pinched on October 24, 1950. At weekly intervals, from the 12th week after pinching to flowering, or 26 weeks after pinching, the following treatments were made:

One and 3 consecutive nights at 40° F minimum temperature. Each treatment consisted of 6 plants. Twelve check plants remained in the carnation house at a minimum night temperature ot 50° F.

EFFECTS OF CONSTANT AND VARIABLE DAY TEMPERATURES WITH LOW LIGHT INTENSITY

To test the effects of both continuous and intermittent low temperature treatments under low light intensities the following experiments were made.

Experiment 3:—Eighteen Frosted Pink Patrician carnation plants per treatment were subjected to the following treatments during the period from September 15, to October 29, 1951. Plants received low light intensities while in the 50° F chambers. When plants were moved to chambers other than 50° F, they received normal sunlight. The 85-60° F treatments involved moving plants from 50° F directly to 85° F. The temperature then fluctuated from a maximum of 85° F during the day to 60° F at night.

1. 24 hours at 50° F.
2. 72 hours at 50° F.
3. 168 hours at 50° F.
4. 24 hours at 50° F, 92 hours at 50° F minimum nights and 75° maximum day temperature, and then 48 hours at 50° F.
5. 36 hours at 50° F and moved to 85° F.
6. 96 hours at 50° F, moved to 85 to 60° F for 24 hours, and then back to 50° for 24 hours.

7. 96 hours at 50° F, moved to 85 to 60° F for 24 hours and then back to 50° F for 48 hours.
8. 144 hours at 50° F, moved to 85 to 60° F for 72 hours, and then back to 50° F for 120 hours.

Bud stage, at time of treatment, was just as the calyces on the most advanced buds were opening. Untreated plants were used for comparison.

Experiment 4:--On February 15, 1952, 10 Frosted Pink Patrician plants per treatment were placed in the refrigerators at 50° and 55-60° F and low light for 47 days. The bud stage at time of treatment was that just prior to calyx opening. Untreated check plants were used for comparison.

Experiment 5:--Plants of Frosted Pink Patrician were selected with buds at a uniform stage, each with the calyx just starting to open. Plants with 11 buds per treatment were placed in 50° and 55° F temperature chambers with low light on April 3, 1952, for 7 consecutive days. Untreated buds of the same stage served for comparison.

Experiment 6:--Treatments of 4 and 5 consecutive days at 50° and 55° F and low light were started April 10, 1952. Bud stage at time of treatment was at the calyx-opening stage. Each treatment consisted of 10 Frosted Pink Patrician plants. Check plants remained in the carnation house.

Experiment 7:--Ten Frosted Pink Patrician plants per treatment, with buds just prior to calyx opening, were subjected to the following intermittent temperature and light treatments beginning April 26, 1952. The plants were placed in 50° and 55° F chambers with low light for 24 hours, then moved to a carnation house at 50-70° F with normal light for 72 hours. This set of conditions was repeated for 1, 2, 3, and 4 consecutive times making a total of 8 treatments and a check.

EFFECT OF LOW TEMPERATURE, LOW LIGHT,
AND TWO SOIL MOISTURES

Experiment 8:--Six 12-inch pots of White Patrician, with 3 plants per pot, were placed in 50 and 55° F and low light chambers on March 11, 1952. The temperature treatments were further divided into high and low moisture levels, with the high moisture maintained at 0 to 3 inches of mercury tension and the low moisture at 0 to 9 inches. These plants remained in the temperature chambers from the calyx opening to the flowering stage or until April 21, 1952. Untreated plants at similar moisture levels were used as checks.

Correlation of calyx splitting and mean day temperature:--Daily records on the date and extent of splitting were kept, on a bench of Frosted Pink Patrician containing

216 plants, from February to May, 1952. A correlation of splitting and mean day temperatures was made using the correlation formula (25)

$$r = \frac{N\,SXY - SXSY}{\sqrt{\left[NSX^2 - (SX)^2\right]\left[NSY^2 - (SY)^2\right]}}$$

Chapter IV

ANALYSIS OF DATA

From June, 1950, to June, 1952, a group of preliminary experiments were carried on at the Colorado Agricultural Experiment Station Greenhouses to obtain information regarding the effects of different temperatures on carnation calyx splitting. Of prime interest were the effects of low night temperatures and continuous low day temperatures with low light intensity on calyx splitting.

Analysis of variance (25) was applied where practical to determine the significant differences between temperature treatments. The check plants received a higher light intensity than most treatments so that statistically they should not be compared with the temperature treatments receiving low light intensities. The small number of plants used in these preliminary experiments and the large variability between plants makes the use of analysis of variance impractical in many cases.

Time of calyx splitting:--During the period from 1948 to 1951, carnation calyx splitting occurred, with few exceptions, at about the same periods each year (Figs. 2 and 4). Splitting also occurred at the same times at the Ralph Hill Greenhouses in Denver and the Colorado Agricultural Experiment Station Greenhouses in Fort Collins.

The splitting started in mid October, increased until late February, when the first peak splitting period occurred. Three high splitting periods occurred each year at about 4-week intervals, late February to early March, late March to early April, and late April to early May.

Total flower production (Figs. 3 and 5) varied from year to year, but the weekly production for each greenhouse remained fairly constant throughout the splitting periods, increasing rather than decreasing.

Stage of bud at time of calyx splitting:—Table 1 shows a variation of from 1 to 12 days from calyx opening to calyx splitting, with an average of 4.46 days from calyx opening to calyx splitting for the 24-day period April 11 to May 5, 1951. Of the 443 buds observed, 372 buds showed calyx splitting tendencies, 201 of which were fully split.

The average number of days from calyx opening to cutting of the flowers was 17 to 18 days during this late spring period.

EFFECTS OF LOW NIGHT TEMPERATURE

Experiment 1:—When plants were subjected to 40° F minimum night temperatures for 1, 3, and 7 nights, differences in their splitting responses were not consistent (Table 2). The untreated plants produced more split calyces than any treatment.

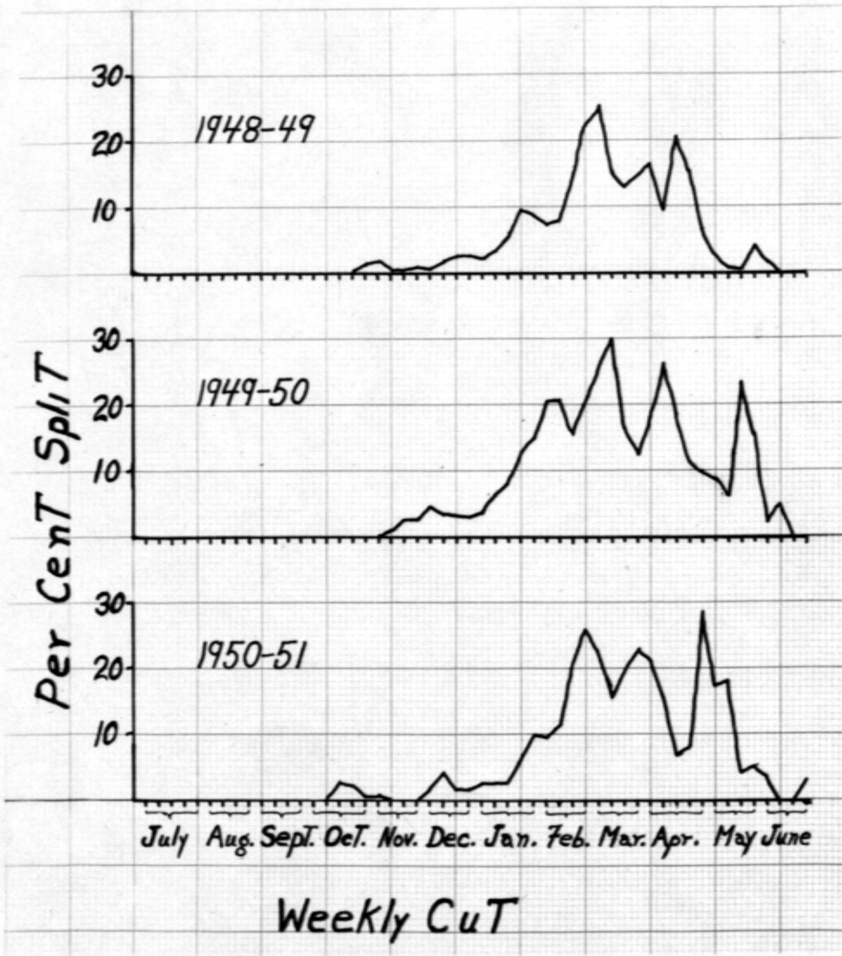

Fig. 2. Weekly percentage of split White Patrician carnations produced at the Ralph Hill Greenhouses, Denver, Colorado, for the years 1948 to 1951.

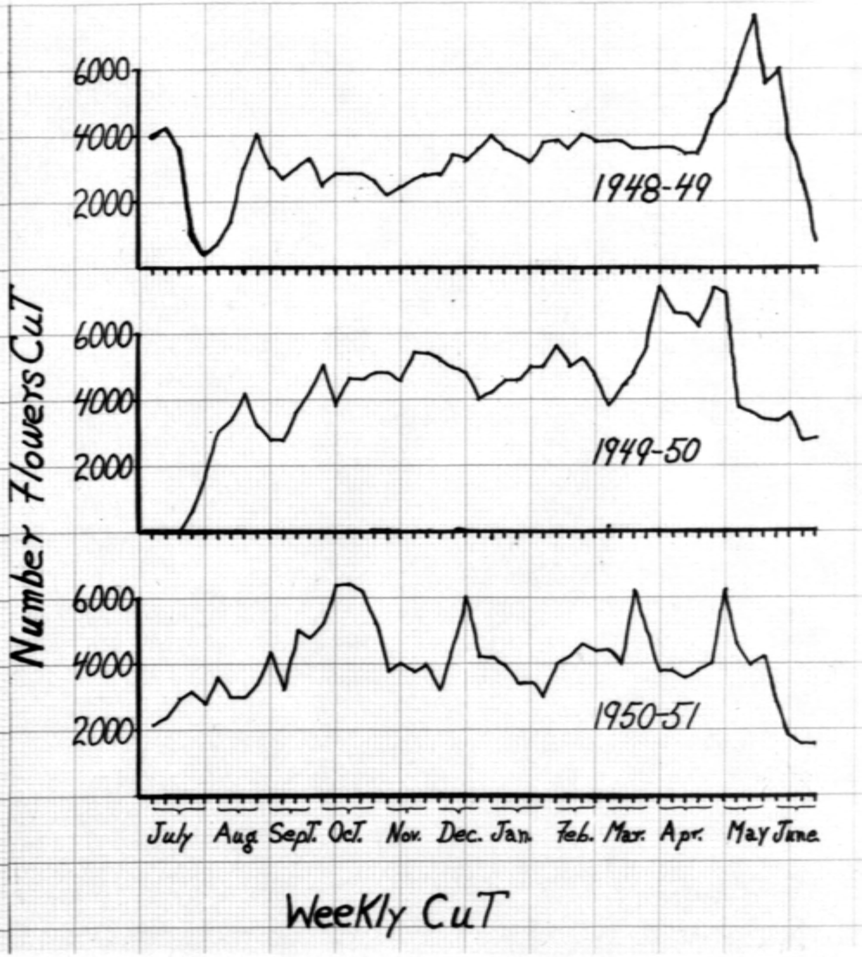

Fig. 3 Total weekly production of White Patrician carnations produced at the Ralph Hill Greenhouses, Denver, Colorado, for the years 1948 to 1951.

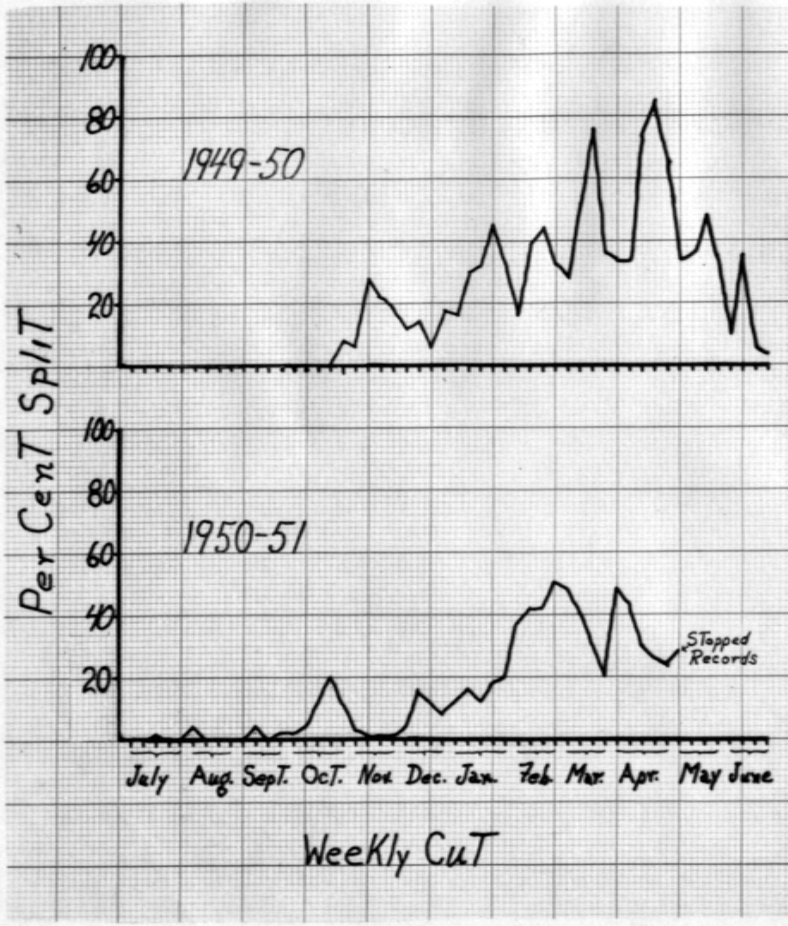

Fig. 4 Weekly percentage of split White Patrician carnations produced at the Colorado Agricultural Experiment Station Greenhouses, Fort Collins, Colorado, for the years 1949 to 1951.

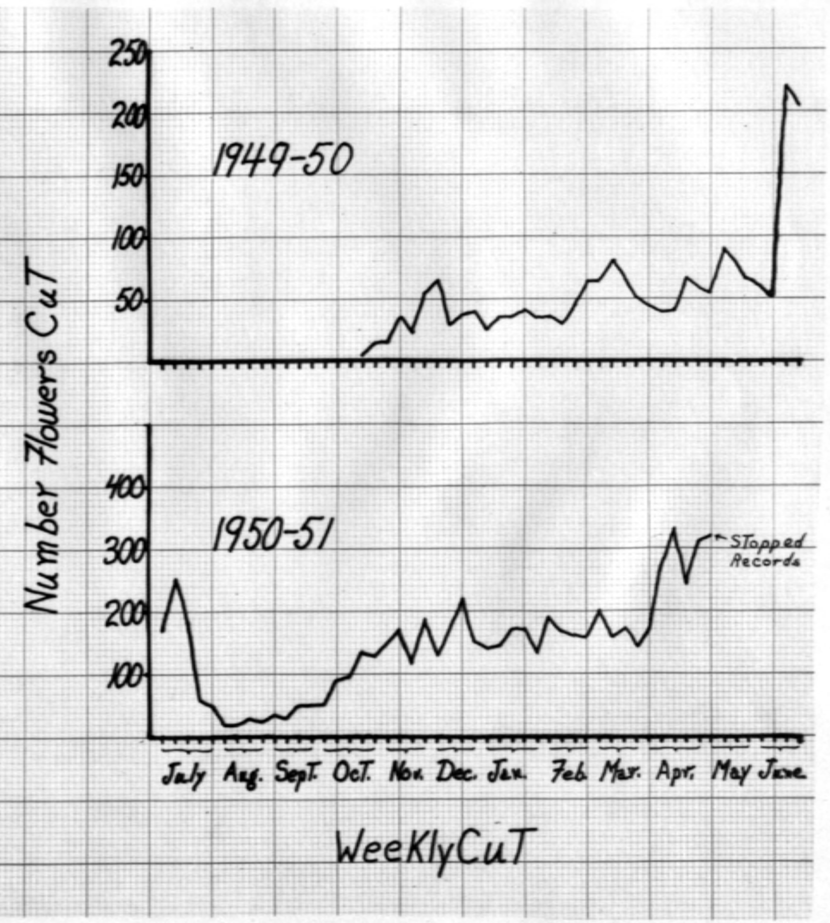

Fig. 5. Total weekly production of White Patrician carnations produced at the Colorado Agricultural Experiment Station Greenhouses, Fort Collins, Colorado, for the years 1949 to 1951.

Table 1. The number of days from calyx opening to the occurrence of calyx splitting.

Date calyx opens	No. days after calyx opening when calyx splitting begins 1	2	3	4	5	6	7	8	9	10	11	12	Average no. of days from calyx opening to calyx splitting	Number of splitting calyces	Number of non-splitting calyces
4/11	.	.	1	.	.	.	.	.	.	.	.	.	3.00	1	0
4/12	.	.	.	.	1	.	.	.	.	.	.	.	5.00	1	0
4/13	.	1	.	1	2	.	.	.	.	.	.	.	4.00	4	0
4/14	.	.	1	.	3	.	.	.	.	.	.	.	4.50	4	1
4/15	.	.	2	2	5	4	.	.	.	.	.	.	4.85	13	3
4/16	.	.	1	3	3	1	1	.	.	.	.	.	4.78	9	2
4/17	.	.	3	4	1	2	.	1	.	.	.	.	4.55	11	2
4/18	.	.	6	3	4	2	2	.	.	.	1	.	4.87	18	6
4/19	2	2	1	2	6	5	2	3	1	.	.	.	5.16	24	7
4/20	1	1	2	3	8	4	3	1	.	.	1	.	5.20	24	10
4/21	.	.	1	2	1	2	1	1	.	.	.	.	5.38	8	2
4/22	.	.	3	.	3	2	5	1	.	.	.	.	5.64	14	6
4/23	.	2	2	3	6	4	2	3	.	.	.	.	5.18	22	4
4/24	2	3	1	9	18	5	1	2	.	.	.	.	4.63	41	6
4/25	.	.	2	4	13	2	1	.	.	.	.	.	4.82	22	3
4/26	.	.	5	7	7	3	.	2	2	.	.	.	5.00	26	3
4/27	.	4	11	1	1	.	1	.	.	.	.	.	3.17	18	2
4/28	.	4	7	5	3	2	2	.	.	.	.	.	3.91	23	4
4/29	4	8	6	5	11	5	.	.	.	.	.	.	3.67	39	5
4/30	.	.	.	9	5	.	.	.	.	.	.	.	4.36	14	0
5/1	.	.	4	16	.	.	.	.	.	.	.	.	3.80	20	0
5/2	.	2	8	.	.	.	.	.	.	.	.	.	2.80	10	1
5/3	1	5	.	.	.	.	.	.	.	.	.	.	1.83	6	3
5/4	.	.	.	.	.	.	.	.	.	.	.	.	0.00	0	1
Total	10	32	69	77	101	43	21	14	3	0	2	0	4.46	372	71
No. full split	6	24	35	39	48	30	7	6	4	0	1	1	4.43	201	
Grand total (split and non-split)															443

Table 2. Percentage of split calyces for treatments of 1, 3, and 7 consecutive cold nights at intervals of 10, 14, and 18 weeks after pinching.

Treatment	Weeks after pinch	Percentage of full splits
1 cold night	10	29.2
	14	8.0
	18	4.4
3 cold nights	10	29.6
	14	16.0
	18	0.0
7 cold nights	10	8.3
	14	13.6
	18	20.8
Check		36.8

Experiment 2:—Treatments of 1 and 3 cold nights at weekly intervals from 12 to 26 weeks after pinching gave a variation in split calyces from 15.8 to 54.2 per cent within the treatments (Table 3). The average of 2 check treatments (53.4 per cent) was approximately equal to the greatest splitting response from any treatment.

Table 3. Percentage of split calyces for cold treatments of 1 and 3 nights at bud stages from 12 to 26 weeks after pinching.

Treatment	Weeks after pinching	Percentage of full splits
1 cold night	12	33.3
	13	31.8
	14	45.8
	15	37.5
	16	29.2
	17	26.1
	18	30.0
	19	34.8
	20	34.8
	21	52.2
	22	17.4
	23	16.0
	24	20.8
	25	17.4
	26	34.8
3 cold nights	12	20.8
	13	25.0
	14	21.7
	15	16.7
	16	45.8
	17	54.2
	18	15.8
	19	33.3
	20	33.3
	21	45.8
	22	30.4
	23	28.6
	24	50.0
	25	29.2
	26	18.2
Check A	--	66.7
Check B	--	40.0

EFFECTS OF CONSTANT AND VARIABLE DAY TEMPERATURES WITH LOW LIGHT INTENSITY

Experiment 3:--Variable temperature treatments during the period September 15 to October 29, 1951 produced no fully split calyces.

Table 4 gives the number of flowers and the percentages of partially split calyces per treatment. Treatment 8 (144 hours at 50° F with low light, 72 hours at 85 to 60° F with normal light intensity, then moved back into the 50° F and low light intensity for 120 hours before being returned to the carnation house) produced 25.0 per cent partially split calyces. Second highest percentage of partially split calyces (14.3 per cent) was produced by treatment 5 (36 hours at 50° F with low light, then moved directly to 85° F). The check plants had 9.9 per cent partially split calyces.

Experiment 4:--Two treatments of 50 and 55-60° F with low light intensity were placed in the chambers February 15, 1951, at a bud stage prior to calyx opening and left for 47 days. The thermostat stuck in the 50° F chamber and froze that treatment 13 days after the treatment began. The 55-60° F treatment produced 31 flowers, 45.2 per cent of which had split calyces, while the check treatment produced 38 flowers and only 18.4 per cent splits.

Table 4. Percentage of partial splitting for variable temperature treatments at calyx-opening bud stage during the period from September 15 to October 29, 1951.

Treatment[a]	Number of flowers	Per cent of partially split calyces
1. 24 hrs. at 50° F	83	4.8
2. 72 hrs. at 50° F	63	8.7
3. 168 hrs. at 50° F	45	4.5
4. 24 hrs. at 50° F, 92 hrs. at 50-75° F, and 48 hrs. at 50° F	84	10.7
5. 36 hrs. at 50° F, and moved directly to 85° F	77	14.3
6. 96 hrs. at 50° F, 24 hrs. at 85-60° F, and 24 hrs. at 50° F	87	8.0
7. 96 hrs. at 50° F, 24 hrs. at 85-60° F, and 48 hrs. at 50° F	95	11.6
8. 144 hrs. at 50° F, 72 hrs. at 85-60° F, and 120 hrs. at 50° F	36	25.0
9. Check	60	9.9

[a] All treatments received low light intensity while in 50° F chambers.

Experiment 5:--When 11 uniform buds at the calyx-opening stage were subjected to constant temperatures of 50 and 55° F with low light intensity for 7 days, the trend was toward more splitting at the 55° F temperature. However, the differences between treatments and the check were not noticeably different. Table 5 gives the percentages of split calyces for each treatment.

Table 5. The effects of 7 consecutive cool days with low light intensity when selected carnation buds were treated at the calyx-opening stage.

Treatment	Number plants	Number flowers	Percentage of split calyces
Seven days at 50° F	4	11	18.2
Seven days at 55° F	5	11	23.1
Check	10	32	15.6

Experiment 6:--Treatments of buds at the calyx-opening stage for 4 and 5 days at 50 and 55° F with low light intensity produced no consistent differences between treatments (Table 6). All treatments except one increased calyx splitting over the untreated check.

Table 6. The effect of 4 and 5 consecutive days of low temperature with low light intensity when selected carnation buds were treated at the calyx-opening stage.

Treatment	Date	Number flowers	Percentage of splits
Four days at 50° F	April 19	35	0.0
Five days at 50° F	April 19	37	5.4
Four days at 55° F	April 19	36	8.3
Five days at 55° F	April 19	37	24.4
Check		35	0.0

Experiment 7:--Carnation plants subjected to various intermittent 50 and 55° F temperatures from April 26 to May 8, 1952, yielded similar percentages of split calyces for both temperatures. Untreated plants, which remained in the greenhouse throughout this period, produced no splits. Results were not noticeably different (Table 7).

Table 7. The effect of intermittent temperature treatments on carnation buds at the calyx-opening stage during the period from April 26 to May 8, 1952.

Treatment	Dates of treatment	Number flowers	Percentage split
One day at 50° F	April 26	34	2.9
One day at 50° F	April 26 and 30	34	5.9
One day at 50° F	April 26, 30, and May 4	36	0.0
One day at 50° F	April 26, 30, May 4, and 8	38	2.6
One day at 55° F	April 26	36	5.6
One day at 55° F	April 26 and 30	35	8.6
One day at 55° F	April 26, 30, and May 4	37	0.0
One day at 55° F	April 26, 30, May 4, and 8	40	2.5
Check		35	0.0

EFFECTS OF LOW TEMPERATURE, LOW LIGHT, AND TWO SOIL MOISTURES

Experiment 8:--Carnation plants with buds at the calyx-opening stage were placed in temperature chambers March 11, 1951, at 50 and 55-60° F with low light intensity. One-half of the plants in each treatment were maintained at high soil moisture (0-3 inches of mercury tension) and the other half maintained at a low soil moisture (0-9 inches tension). After 41 days in the chamber the 50° F treatment had produced only 4 flowers and no splits. With high moisture, the 55-60° F treatment produced 22 flowers, 36.4 per cent of which were split.

With low moisture, the 55-60° F treatment produced 17 flowers, 23.5 per cent of which were split (Table 8). The 55-60° F treatment produced significantly less splits than the untreated checks which remained in the greenhouse (Table 9). During the period from March 11 to April 21 the night temperature in the greenhouse was 50° F and the mean day temperature fluctuated from 52° to 74° F. Results from the 50° F treatment were insufficient to warrant analysis. The differences between moisture levels were not significant.

Table 8. The effect of constant temperature treatments with low light intensity and 2 levels of soil moisture on the calyx splitting of carnation buds treated at the calyx-opening stage.

Treatments: Temperature	Treatments: Moisture	Number of flowers	Percentage of split calyces
50° F (constant)	High	3	0.0
50° F (constant)	Low	1	0.0
55-60° F (constant)	High	22	36.4
55-60° F (constant)	Low	17	23.5
Check (50-74° F mean day temp.)	High	22	77.3
Check (50-74° F mean day temp.)	Low	23	69.6

Table 9. Table of variance for effects of low temperature, low light, and 2 soil moistures.

Variation due to:	D.F.	Sums squares	Mean square	F-value
Blocks	2	0.0704	0.0352	
Treatments[/a]	1	2.1421	2.1421	8.3938*
Moistures	1	0.0752	0.0752	
Moistures x treatments	1	0.0310	0.0310	
Error	6	1.5314	0.2552	
Total	11	3.7093		

/a The 50° F treatment was left out because of insufficient results.

* Exceeds the 5 per cent level

Correlation of calyx splitting and mean day temperature:--Table 10 gives the mean day temperatures in the carnation greenhouses at Fort Collins, Colorado, for 12- and 24-hour periods from February 22 to May 9, 1952. Daily records of the production of split calyces on 216 Frosted Pink Patrician carnation plants are also included in this table.

During the period from February 24 to March 31, there are correlation coefficients (Table 11) of 0.5853 and 0.5970 between split calyces and the 12- and 24-hour mean day temperatures, i.e., for the day the splitting occurred. These data show that the higher the temperature, the more splits were produced. Correlation coefficients

Table 10. The daily occurrence of split calyces on 216 carnation plants and the mean daily 12- and 24-hour temperatures recorded in the greenhouse at Fort Collins, Colorado, during the period from February 22 to May 9, 1952.

Date	No. split	Mean 12 hr. day temp.	Mean 24 hr. day temp.
Feb.			
22	--	61.3	56.1
23	--	57.0	54.4
24	4	57.4	54.5
25	4	57.0	54.5
26	4	59.7	55.3
27	2	61.3	56.5
28	5	63.8	57.9
29	13	60.3	56.1
Mar.			
1	4	57.7	54.0
2	4	56.1	53.7
3	3	56.0	55.4
4	5	59.4	55.6
5	2	57.0	54.4
6	1	60.7	56.3
7	4	60.8	56.8
8	3	59.3	55.6
9	12	64.9	58.9
10	10	60.1	55.9
11	7	59.4	55.5
12	1	58.3	54.8
13	3	57.0	54.1
14	2	57.6	54.3
15	6	59.4	55.5
16	7	59.4	55.0
17	3	61.5	58.8
18	16	59.8	57.8
19	10	65.7	61.1
20	14	59.6	58.3
21	2	55.0	54.4
22	2	52.0	51.5
23	7	56.1	53.9
24	4	59.9	55.6
25	4	56.4	53.8
26	11	60.3	56.0
27	14	62.7	57.1
28	17	64.0	57.9
29	17	66.9	59.5
30	6	61.3	56.8
31	7	64.3	58.7
April			
1	3	60.2	56.2
2	11	63.2	57.9
3	11	61.5	57.1
4	15	63.0	57.6
5	12	64.6	58.7
6	23	69.1	61.5
7	24	72.2	63.8
8	4	68.9	62.7
9	4	54.5	52.6
10	1	59.4	55.5
11	5	62.8	57.2
12	2	56.8	54.2
13	4	61.7	56.4
14	1	61.7	57.1
15	3	64.4	59.4
16	9	60.5	56.7
17	1	61.0	57.1
18	7	69.7	62.8
19	16	73.9	64.8
20	12	73.2	64.4
21	10	69.4	62.5
22	3	54.5	53.3
23	5	57.8	54.7
24	4	67.5	61.0
25	11	71.9	63.8
26	11	71.5	63.6
27	14	79.5	68.6
28	8	78.0	67.6
29	5	66.5	60.7
30	1	61.0	57.2
May			
1	5	65.5	59.3
2	4	72.8	64.5
3	4	77.5	67.8
4	5	77.8	68.3
5	5	78.8	68.8
6	4	74.3	67.0
7	2	69.9	63.5
8	-	72.8	65.6
9	-	70.8	63.5
Total	509		

for the same period of splitting, but with the temperature the day previous to splitting were 0.6949 and 0.5056. These correlation coefficients are significant to the 1 per cent level. Correlation coefficients for the temperature two days before splitting were not significant. The period from April 1 to May 8 showed significance at the 5 per cent level for the 12-hour mean temperature for the same day the split calyx occurred. No significance was shown for temperature correlations for 1 and 2 days previous to splitting.

Table 11. Correlation coefficients for number of split calyces and the mean 12 and 24-hour day temperatures in the greenhouse for the same day, 1, and 2 days before the calyx split occurred.

Period of time	Day of correlation	Correlation coefficient 12-hour mean day temp.	Correlation coefficient 24-hour mean day temp.
Feb. 24 to April 1, 1952	Same day	0.5853**	0.5970**
	1 day before	0.6949**	0.5056**
	2 days before	0.1624	0.1098
April 1 to May 8, 1952	Same day	0.3421*	0.2892
	1 day before	0.1116	0.0812
	2 days before	0.1343	0.1861

* Significance at 5 per cent level
** Significance at 1 per cent level

Chapter V

DISCUSSION OF RESULTS

Many factors have been suggested as probable causes of carnation calyx splitting. The factors which affect carnation calyx splitting appear to be common to all greenhouses within a given area. Calyx splitting in the Denver-Fort Collins, Colorado area starts in October and increases until late February, when the first peak splitting period is reached (Figs. 2, 4). Since splitting occurs at the same time of the year in Denver and Fort Collins, although the methods of growing (watering, fertilizing, soil, time of planting, location of benches, etc.) are not the same, it appears that some factor or factors, other than growing methods, cause calyx splitting. The factors most likely to be common to greenhouses within a given area are temperature and light conditions.

In all research covered in the review of literature, the records for calyx splitting were taken on the total per cent of split calyces on flowers cut over a period of several months. Individual calyces were found to split any time from the calyx-opening stage to approximately 5 days before the flower was cut. Calyces that split on the same day may be cut over a period of at least 15 days, depending on the temperature under which the plants are growing.

Correlation of mean 12-hour day temperatures with the occurrence of splitting (Table 12) indicates that periodic high temperatures the day of splitting and, under some temperature conditions, the day before splitting occurred, are factors which cause the calyces to split.

Low night temperatures for 1 or 3 consecutive nights at any bud stage from flower bud initiation to cutting of the flower, had no significant effect on splitting. Variable, and low intermittent day temperatures seemed to have no effects on splitting. The treatments of variable day temperatures during September and October produced no splitting. This suggests that carnations may require a cool preconditioning period before splitting may occur.

Constant temperatures of 55-60° F from calyx-opening bud stage to the time flowers were cut showed a significant reduction in splitting over the check treatments which remained in the carnation greenhouse (Table 8). However, a similar treatment earlier in the spring produced more split calyces on the plants in the temperature chamber than on the check plants (Exp. 4).

All temperature treatments except one showed insignificant and inconsistent results. Two probable factors which may have affected the results are the small number of plants and flowers per treatment, and the retarding effect of low temperature on the plant growth-rate. After buds of a uniform stage are given different temperature treatments, the buds in each treatment are in a different stage of development. When returned to the greenhouse, periodic high temperatures could affect the buds from one treatment and not those from another. The treatment in which the calyces are at the stage susceptible to splitting would show the highest percentage of splits.

Timing of flower production probably has a lot to do with the wide disagreement in reported causes of carnation calyx splitting. Any treatment which causes a change in the flowering time of carnation plants could change the production of splits by those plants. If periodic high temperatures are the cause of splitting, the treatments which are at the proper stage for splitting during the occurrence of such temperatures will show the significant results.

Temperature conditions required to produce split calyces seem to vary according to the previous temperatures. When plants have been growing under warm temperatures during the summer and fall, low temperatures seem to have little effect on splitting. However, when plants have been growing during the cool season, warmer than normal day temperatures will produce split calyces. As the plants become accustomed to warmer temperatures, still higher temperatures are required to produce splitting. Previous temperatures at which carnation plants have been growing should be considered when attempting to analyze the cause of carnation calyx splitting. Each variety or individual selection within a variety will be effected differently by the same set of temperature conditions.

From the results of this investigation it is postulated that carnation calyx splitting is caused by fluctuating day temperatures. Temperatures which cause splitting will vary according to the previous temperatures under which the plants have been growing. Other factors that have been reported as causing splitting are related to splitting only as they affect the growth and quality of the carnation.

Theoretically the control for carnation calyx splitting would be careful control of the temperatures within the greenhouse, allowing no sharp rises or drops in temperature. Temperatures should be maintained within a few degrees of the mean of the previous day.

Suggestions for further investigation:--The techniques of gathering data for correlation of actual splitting with the mean temperature should be refined. This could be done by calculating the per cent of split calyces of the potential calyces that could split each day. To make the calculation of the potential number of calyces that could split the following data would be needed:

date of calyx opening, date of calyx splitting, and date flower is cut. This sort of study would require a steady production of at least 56 flowers per week from October to June. Accurate correlations could then be made on temperature-splitting relationships at any specific bud stage.

Chapter VI

SUMMARY

Preliminary investigations were made to determine the effects of temperature relationships on carnation calyx splitting.

1. Carnation calyx splitting started in the Denver- Fort Collins, Colorado area in October and increased until late February, when the first peak splitting period occurred. Two more splitting periods followed at about 4-week intervals. This same pattern of splitting was evident from 1948-51.
2. The actual splitting of the calyx occurred from 1 to 12 days after calyx opening (average 4.46 days).
3. Low minimum night temperature treatments of 40° F for 1 or 3 consecutive nights at weekly intervals from flower bud initiation to flowering produced no increase in splitting.

4. Constant temperatures of 55-60° F from calyx-opening bud stage to flowering showed significant reduction in splitting over the check. The check treatment remained in the carnation house where the mean day temperature varied from 52 to 74° F. All other temperature treatments showed insignificant or inconsistent results.

5. There was a significant positive correlation between splitting and the mean day temperatures on which splitting occurred, i.e., the higher the mean day temperature the greater the number of splits.

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A P P E N D I X

APPENDIX A

The following investigations were carried on simultaneously with the temperature treatments.

Side on which calyx splits:--In an attempt to determine directional influence on calyx splitting, the position of the separation of the calyx tube was recorded according to the 4 points of the compass. These records involved 372 split calyces on an outside north bench during the 1950-51 season, and 509 split calyces on a south bench (second in from the side) during the 1951-52 season. A Chi-square "goodness of fit" test was used to analyze the results.

The separation in the calyx was found to occur most often on the north and west sides, during the 1950-51 season. The following year, records on the second bench in from the south side of house showed that the largest amount of calyx splitting occurred on the west and south sides of the calyx. Table A gives the observed frequency of splitting and the Chi-square values. Significant differences are shown in the first year's records on the north bench. The side of the bud nearest the outside of the greenhouse seems most prone to splitting.

Table A. Observed directional frequence of splitting and the Chi square values.

Year	Bench	Side on which split occurs North	South	East	West	χ^2	P
1951	North	150	91	70	135	37.460**	.01
1952	Second from the south	98	102	74	109	7.235	.068

**Significant to the 1 per cent level

Diurnal movement of the bud while the calyx is opening:—To determine if the bud turns while the calyx opens, time-lapse photography was used on 3 buds of Frosted Pink Patrician over a 24 hour period. Ten 16 mm movie frames were taken every 10 minutes. The time-lapse film taken over a period of 24 hours showed no diurnal movement of the buds.

Inherence of splitting:—From the 1950-51 studies on Frosted Pink Patrician 12 plants which had produced no split calyces and 12 plants which had split all calyces during April and May were planted in a bench and splitting records kept from February to May 1952.

The non-splitting plants produced 11.3 per cent split calyces, while the splitting plants had 29.2 per cent split calyces during the period from February to May. The results appear in Table B. The selections within the variety varied widely in their splitting tendencies.

Table B. Percentage of splitting for selected non-splitting and splitting plants held over for a second year's production.

Treatment	Number of flowers	Percentage not split	Percentage partially split	Percentage fully split
Non-splitting plants during the spring of 1951	71	53.5	35.2	11.3
Splitting plants during the spring of 1951	72	6.9	63.9	29.2