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EFFECTS OF TEMPERATURE AUTOMATION ON CARNATIONS

By Charles H. Korns[1/] and W. D. Holley

Optimum day and night temperatures for carnations have been under investigation at Colorado State University for the past 8 years. Schmidt (5) found the best fall, winter and spring night temperature for Sim varieties to be 52 to 54°F. Hanan (1) grew carnations at 52 nights and day temperatures of 60, 65, 70 and 75. The best grade of flowers was obtained for fall, winter and spring at 65, but Hanan opened up the possibility of correlating the day temperature with seasonal changes in light. Manring (3) found such a seasonal light-temperature correlation improved grade and quality of carnation flowers without affecting yield. Hanan had also found that carnation yield was not affected by the day temperatures he used.

Since seasonal correlation of day temperature with light has been found an excellent method for maintaining high grade flowers, the next logical questions are:

1. Can day to day correlation of day or night temperatures with light be used to improve grade or yield?
2. How much additional temperature can carnation plants utilize under high light before grade and quality is impaired?

METHODS AND MATERIALS

This investigation was conducted in the temperature control greenhouse at Colorado State University. The greenhouse is oriented east and west and is divided into 4 compartments of equal size. The compartments were lettered from A to D and from west to east. Each contained 2 benches. The results from this study involving Compartment C were published in CFGA Bul. 149 (2).

The north bench of each compartment was planted January 7, 1961 with 126 uniformally selected White Sim carnations at a 6 x 8 inch spacing. After the plants became established, they were given a single pinch.

The south bench of each compartment was divided into 4 groups of 30 6-inch pots. On January 10, 1961, the first group in each compartment was planted with 30 Pink Sim carnation cuttings. Three weeks later the second group was planted and 3 weeks later the third, etc. After 4 weeks of growth, the plants were pinched to the fifth pair of leaves. The plants were harvested after 12 weeks of growth and a new group started in its place. Beginning with the September 19 planting, White Sim carnations were used. All cuttings weighed from 6 to 8 grams prior to rooting.

1/ This is a part of the thesis completed by Charles H. Korns for the M.S. Degree in Horticulture at Colorado State University.

Experiment I

Temperatures in the automated compartments (A and B) were controlled with a 2 degree differential between the 3 light levels (Table 1). Compartment A had automatically adjusted days, and constant nights, while B had automatically adjusted days and nights. Seasonal temperature adjustments were made in D. Results of the treatment effects in this experiment are based on measurements made from the beginning of the experiment to July 2, and from September 10 to January 27, 1962.

The mean grade (Table 3) of flowers produced under automatically adjusted days (A) was significantly higher than those produced under seasonally adjusted days and nights (D). The data on % grade distribution and reasons for downgrading in the same table indicate that the higher mean grade resulted from a greater number of fancy flowers and fewer designs. The malformation rate was lowest under automatically adjusted days.

Table 1. The temperature regimen for Experiment I (January 7, 1961 to January 24, 1962)

Compartment	Light level	Cool to Day	Cool to Night	Heat to Day	Heat to Night	Vent closes Day	Vent closes Night	Vent opens Day	Vent opens Night
A	High	63	63	61	52	62	62	65	65
	Normal	61	61	59	52	60	60	63	63
	Low	59	59	57	52	58	58	61	61
B	High	63	63	61	54	62	62	65	65
	Normal	61	61	59	52	60	60	63	63
	Low	59	59	57	50	58	58	61	61
D	March 15 to October 15	65	65	60	54	64	64	67	67
	October 15 to March 15	62	62	60	52	61	61	64	64

1. The thermostats used in compartments A and B were accurate to 0.1° while those in D to 1.5°.
2. From June 10, 1961 to September 10, 1962, all compartments were cooled to 65 and the vents were opened continuously.

Table 2. The temperature regimen for Experiment II (January 24, 1962 to May 10, 1962)

Compartment	Light Level	Cool to Day	Cool to Night	Heat to Day	Heat to Night	Vent closes Day	Vent closes Night	Vent opens Day	Vent opens Night
A	High	69	69	65	53	67	67	71	71
	Normal	65	65	61	53	63	63	67	67
	Low	61	61	57	53	59	59	63	63
B	High	69	69	65	56	67	67	71	71
	Normal	65	65	61	53	63	63	67	67
	Low	61	61	57	50	59	59	63	63
D	March 15 to October 15	65	65	60	54	64	64	67	67
	October 15 to March 15	62	62	60	52	61	61	64	64

Seasonally adjusted day and night temperatures (D) produced heavier fancy and standard grade flowers (Table 3) when compared to those produced with automatically adjusted day and constant night temperatures (A). The highest fresh weights occurred under automatically adjusted temperatures and lowest light, i.e. November through January.

Although the data in Table 3 show considerable differences in yield, statistical analysis did not indicate significance. The lower yield under automatically adjusted day and night temperatures (B) is somewhat substantiated by the slower rate of bud development (Table 4).

Table 3. Summary of Production on White Sim Carnations Benched January 7,1961, Experiment I.

	Compartment A	Compartment B	Compartment D
Number of flowers cut	938	792	1012
Mean grade (LSD 5% level 0.11)[a]	4.69	4.61	4.58
Mean fresh weight of cut flowers			
Fancy	30.3	30.7	31.0
Standard	21.4	20.3	22.1
Percent distribution of grade			
Fancy	80	78	74
Standard	14	13	17
Short	2	2	2
Design	4	7	7
Percent flowers downgraded			
Insufficient weight	4.9	6.7	4.2
Insufficient stem length	6.3	5.1	10.2
Inferior flowers and weak stems	4.9	4.3	4.1
Split calyxes	0.7	1.1	1.4
Bullheads	0.8	1.7	1.8
Slabs	1.3	2.5	2.5
Hollow centers	1.1	0.6	1.2

a based on 4-week means

Table 4. Mean Number of Days From One Quarter Inch Bud Diameter to Harvest Date. Experiment 1.

Compartment	9/13	10/11	11/8	11/15	11/22	11/29	12/6	Mean (LSD 5 per cent level 1.6)
	Date buds one-quarter inch in diameter[a]							
A	51.3	51.2	52.4	52.6	56.2	54.8	53.4	53.1
B	51.5	51.2	56.4	55.0	60.8	57.8	57.0	55.7
D	46.5	49.8	53.0	54.0	56.6	57.4	58.0	53.6

[a]Five buds measured per sample.

When young carnation plants were grown for 12 weeks in the several temperature combinations, automatically adjusted day and night temperatures (B) produced the least dry matter increment (Table 5). This dry matter accumulation was increased in significant steps by (1) automatic adjustment of day and constant night temperature, and (2) seasonal adjustment of both night and day temperature.

Table 5. Mean Increase in Dry Weight and Per Cent of Dry Matter in Young Sim Carnation Plants Grown for 12 Weeks in 6-inch Pots. Experiment 1.

Growth period	Dry weight increase as % of original weight			% dry matter		
	Compartment			Compartment		
	A	B	D	A	B	D
1/10 to 4/4/61	795	718	767	14.78	14.54	14.65
1/31 to 5/16	861	834	850	14.07	14.15	14.43
2/21 to 5/16	1117	1066	1091	13.94	14.32	14.95
3/14 to 6/6	1129	1192	1368	14.71	13.67	14.59
8/29 to 11/21	612	612	697	13.84	13.79	13.91
9/19 to 12/12	484	460	484	14.34	13.79	14.28
10/10 to 1/2/62	332	312	314	14.85	14.76	15.38
10/31 to 1/23	335	323	393	14.40	14.04	14.67
[illegible]21 to 2/12	394	402	369	13.77	13.13	13.99
Mean	673	657	704	14.30	14.02	14.54
(LSD 5% level)		13			N.S.	

The higher mean increase under seasonally adjusted days and nights resulted from the growth made after March 15 and before October 15 when plants were growing at higher temperatures. Differences between growth periods were highly significant. The mean % dry matter in young plants was not significantly affected by these treatments. This was also true for the % dry matter in the cut flower and flower head (Table 6).

In Table 6, the number of internodes per fancy length stem (counted to the nearest 1/4) and the stem strength appeared to be closely related--the more internodes the greater was the stem strength.

Periodic measurements showed that keeping life of the cut flowers was not influenced by these treatments (Table 6). Variations did occur between sampling dates.

Table 6. Mean Values of Various Measurements Made on White Sim Carnations From September 1, 1961 to February 1, 1962. Experiment I.

Measurements	Number of samples	LSD 5%	Compartment A	B	D
Per cent of dry matter					
Flower and stem	9	N.S.	18.2	18.0	18.4
Flower head	9	0.7	18.6	18.5	19.2
Fresh weight of flower head (g)	9	0.4	9.8	9.6	9.5
Internodes per fancy length stem	8	0.4	7.9	8.1	8.1
Stem strength[a]	5	2.5	6.1	4.8	4.2
Keeping life (days)	6	N.S.	8.2	8.4	8.4

[a]Degrees divergent from horizontal

Experiment II

Temperature differentials in the automatically controlled compartments were increased to 4 degrees between light levels for day control and 3 degrees for night control (Table 2). Experiment II includes measurements made from February 11 to May 10, 1962. The short duration of the experiment limited the value of statistical analysis.

There appeared to be a trend toward a higher mean grade when plants were subjected to automatically adjusted days and constant nights as is shown in Table 7. The lower mean grade under automatically adjusted days and nights resulted from a decrease in the number of fancy flowers produced.

Statistical analysis of the fresh weight of fancy grade flowers (Table 7) indicated differences similar to those in Experiment I. Treatments did not affect the weight of standard grade flowers, or the % dry matter in the cut flowers or flower heads.

Table 7. Summary of Production of White Sim Carnations From February 11, 1962 to May 5, 1962. Experiment II.

	A	B	D
Number of flowers cut	656	592	692
Mean grade	4.72	4.60	4.67
Mean fresh weight of cut flowers			
Fancy (A*-B, D*-A, and D*-B)[a]	28.9	28.1	29.9
Standard (N.S.)	18.4	18.6	18.8
Per cent distribution of trade			
Fancy	77	66	77
Standard	20	31	18
Short	1	1	1
Design	2	2	4

[a]Indicates significance at the 5 per cent level (t analysis)

The rate of bud development (Table 8) was slower under seasonally adjusted days and nights until the temperature was raised March 15. After this date the rate equaled that of the automatically adjusted days and constant nights.

Table 8. Mean Number of Days From One-Quarter Inch Bud Diameter to Harvest Date. Experiment II.

Compartment	Date buds one-quarter inch in diameter[a]								Mean (LSD 5% level 1.7
	1/24	1/31	2/7	2/15	2/21	2/28	3/24	3/28	
A	44.2	45.0	45.2	43.2	43.6	41.0	42.0	40.8	43.1
B	46.0	44.4	43.8	43.8	43.2	41.4	40.8	39.8	42.9
D	54.0	51.2	48.4	49.4	46.4	43.8	41.2	41.4	47.0

[a]Five buds measured per sample.

The differences in growth of young plants during the 3 periods of Experiment II (Table 9) were not large enough to be significant. Growth increased with increased automation at these higher temperatures. The % dry matter in the plants after 12 weeks of growth showed no distinct trends.

Table 9. Mean Increase in Dry Weight and % Dry Matter in Young White Sim Carnation Plants Grown for 12 Weeks in 6-inch Pots. Experiment II.

Growth period	Dry weight increase in % of original wt. Compartment A	B	D	% dry matter Compartment A	B	D
1/2 to 3/27	615	665	610	14.06	13.41	13.76
1/23 to 4/17	805	811	670	14.84	14.41	14.81
2/13 to 5/8	1040	1093	1064	15.70	14.75	14.87
Mean	820	856	781	14.87	14.19	14.45

Discussions

Automatic night temperature adjustments in the range of this investigation did not significantly effect the growth of carnations. The lack of such effects allows simplification of the automatic controlling mechanism by eliminating the need for night temperature adjustments.

Carnations grown at automatically adjusted day and constant night temperatures had a higher mean grade than those grown at seasonally adjusted days and nights. The higher mean grade resulted from a reduction in the number of malformed flowers produced. This can be attributed to a more accurate control of temperatures in the automated compartments. Even the 10 degree temperature fluctuation between high and low light in Experiment II (Fig. 4) failed to increase the malformation rate over that obtained in Experiment I. This shows that carnations can tolerate temperature fluctuations of this magnitude as long as they follow available light intensity.

The significant differences obtained in the growth of young plants under the various treatments indicates that at least two factors other than light intensity influence the dry matter increase, namely CO^2 and temperature. Raising the CO^2 level of the atmosphere increased the growth by 12% in the first 2 spring plantings and the last 2 fall plantings of Experiment I (2). The faster growth rate under seasonally adjusted days and nights after March 15 and before October 15 resulted in a higher mean temperature and increased the growth by 12% over that of the automatically adjusted day and constant night temperatures. This is substantiated by the slow growth obtained under automatically adjusted nights from the January, September, and October plantings. During these growth periods the light was seldom at the high level hence these plantings were grown mostly at low or normal temperatures. The growth rate of young plants during low light periods can be more closely correlated with available light intensity by growing at a higher carbon dioxide level and higher temperature. The rate of flower bud development followed the growth of young plants.

Conclusions

1. Automatically adjusting night temperatures with light received during the previous day gave negative results. Seasonally adjusted night temperatures for Colorado presently recommended are:
   - 60° in summer
   - 54-55° September 1 to November 15, and March 15 to June 1.
   - 52° November 15 to March 15.

2. Minute by minute adjustments of day temperature with light shows some promise. The temperature differences allowed in most of this investigation were too small. If warmer temperatures are beneficial with high light intensity, the additional temperature would be free. Results obtained in this investigation on the growth of carnations indicate that it is possible to take advantage of high light by running a higher temperature and increasing the % of time carbon dioxide can be added. A modification of Experiment 2 comparing the automated day temperatures of Table 2 with and without CO^2 fertilization is being completed this year, and should complete this phase of our temperature research.

Cultural Practices

1. The soil was steamed for the north benches as well as for each new planting in pots.
2. A complete nutrient solution was used for irrigation.
3. Steamed leaves were used as a mulch on the north benches after the plants were established.
4. The north benches were watered thoroughly at a tensiometer reading of 300 to 500 millibars. When any of the plants within a group of pots began to wilt, the entire group was watered thoroughly.

Environment

Day temperatures were controlled in compartments A and B by the Ventender System which automatically adjusted temperatures according to the amount of solar energy being received. The solar energy was divided into 3 arbitrary levels--high, normal, and low-- with each level having a different temperature regimen. The night temperature in A was constant throughout the heating season, whereas, in B it was adjusted automatically according to the light level of the previous day--high, normal, or low. Temperatures in D were adjusted manually with seasonal changes in light intensity as recommended by Manring and Holley (4). Temperatures were recorded throughout the investigation.

The automatic temperature controlling mechanism (Fig. 1) used for compartments A and B consists of the following:

Light intensity adjuster (day control)-A phototube (Fig. 2) feeds a signal to the adjuster which visually indicates the light intensity on a galvanometer. The meter has 2 pick-off points which are arbitrarily set on 10 and 20 (approx. 3,000 and 6,000 ft-c). When the intensity is in contact with the low pick-off point, temperatures are controlled on the low level. If between the 2 points, normal level temperatures are controlled; and if in contact with the upper, high level temperatures are controlled.

Light accumulation adjuster (night control)-A solar battery (Fig. 2) feeds a signal to the light integrator where light intensity and time are integrated to give a light accumulation measurement. The accumulated amount is indicated on a face mounted counter. If the accumulated value for the daylight period is between the arbitrarily set points of 13,100 and 18,100 (approx. 290 and 400 gm cal/cm^2), normal night temperatures are controlled.

When below 13,100, low temperatures are controlled and if above 18,100 high temperatures. On November 29 the units were changed to 8,100 and 15,200 (approx. 200 and 350 gm cal/cm^2).

The control temperature selector has selector switches with 11 possible temperature selections for each function in each band of intensity and accumulation. The 11 temperature selections correspond to the 11 thermostats located in the aspirator boxes of each compartment (Fig. 3). A time clock automatically switches from day to night control. Day temperatures are controlled from approximately sunrise to sunset.

Measurements

Records were compiled on the total number of flowers cut (yield), fresh weight of fancy and standard grade flowers, and number of flowers downgraded. Mean grade was calculated.

The % dry matter in the cut flower and flower head weight (head removed at the junction of calyx and stem) of fancy and standard grade flowers was measured at approximately 2-week intervals. Turgid samples were used for fresh weight measurements. Samples were dried at 180° for 72 hrs.

Cut flower life was measured by placing samples of the flowers in 1 gal. of tap water containing 1/4 tsp of sterichlor. The samples were placed in a 33° refrigerator for 24 hrs. then in a 70° keeping chamber. When the petals began to curl and lose turgor, the flower was removed. Keeping life was the number of days from cutting to removal minus 2.

The potted plants were harvested after 12 weeks of growth and the roots removed. The plants were oven-dried at 180° for 72 hrs. Increase in dry matter equaled the dry weight at harvest plus the dry weight of the pinch minus the dry weight of the rooted cutting.

Literature cited

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5. Schmidt, R. G. 1957. Some effects of night temperature on carnations. Thesis M. Sc. Colo. State Univ.

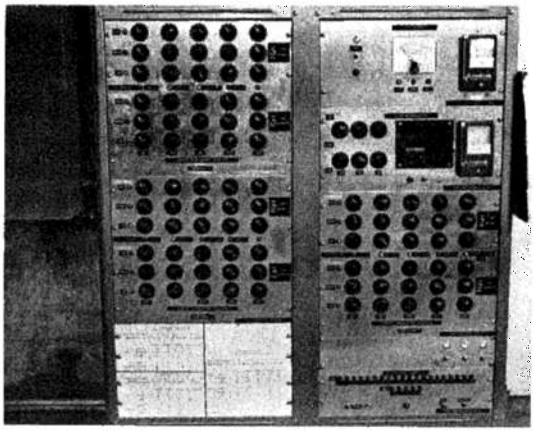

Fig. 1 The Ventender temperature controller designed for this investigation. Each unit of 30 dials operates one temperature regimen.

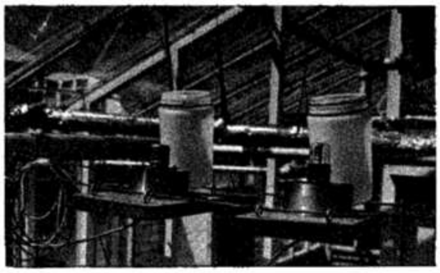

Fig. 2 Solar battery left and phototube with diffuser covers removed.

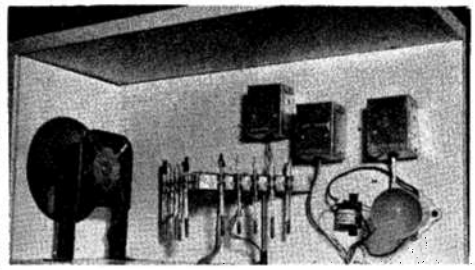

Fig. 3 Aspirator box facing north containing all controls for one compartment.

Your editor, W D Holley

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