Colorado Flower Growers Association Inc.

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Effects of CO2 Concentration and Temperature on Carnations[1]

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Optimum temperatures for growing Sim cultivars of carnations in Colorado have been established in a series of investigations (4, 6, 7). The temperatures indicated by these workers as near optimum are:

Night - 50-52° winter, 54°F fall and spring,
Day - May 15 to September 1, 70°F; September 1 to November 15 and March 15 to May 15, 65°F; and November 15 to March 15, 60°F.

These changes in temperature correspond with seasonal variations in solar energy. While little or no effects of temperature on yield were found by these investigators, grade and quality was maintained when temperatures were seasonally correlated with light. Korns (5) found that minute by minute adjustment of day temperature with light produced higher mean grade of carnations by reducing malformed flowers. Although yield was not affected, his work indicated this method of temperature control was promising. Adjusting night temperature according to the light received during the day gave negative results.

Goldsberry (2) and Korns (5) have reported increased carnation growth when CO_2 levels were increased. In Goldsberry's experiment the outstanding results were increased yield, shorter time between crops and increased percent dry matter for the CO_2 treated plants. Korns found that average CO_2 levels elevated no more than 70 ppm increased growth of young carnation plants 10% and yield of producing plants 15%. While mean grade was not increased, the flowers were slightly heavier in each grade when CO_2 was added.

The relationship between temperature, light and CO_2 assimilation is well known. Gaastra (1) reported threefold increases in CO_2 assimilation of excised cucumber leaves when temperature in a high CO_2 atmosphere was increased from 60 to 93°F. Korns (5) has indicated that carnations may require higher temperatures when levels of light and CO_2 are high. This series of experiments was designed to add to our knowledge on the effects of temperature and CO_2 concentration on carnation growth.

[1] *This paper was presented at the annual meeting of the American Society for Horticultural Science, Boulder, Colorado, August 23-26, 1964.*

Experiment I

A previously described temperature house (3) of four compartments identified A to D was used in this investigation. The compartments are 17-1/2 by 15 feet and contain two 3-1/2 by 12 feet benches. From previous experiments in this house (4, 5, 6, 7) the light factor has been equated to 100-97-100-103 for the respective compartments. This experiment was designed to: 1) determine the effects of additional CO_2 on first-year carnations, and 2) compare the effects of light-correlated day temperatures with those adjusted seasonally. Carbon dioxide was added to compartments C and D (sunrise to sunset) when ventilation was off from September 11 to April 2. No CO_2 was added to A and B. The CO_2 concentration averaged 60 to 75 ppm higher in C and D, requiring 1.18 and 0.92 cu. ft. of CO_2/sq. ft. of area. Day temperatures in compartments B and C were controlled by incident light as follows:

Light inside the greenhouse	Fan on	Vent opening
Low (to 2200 ft-c)	61°F	63°F
Medium (2200 to 4400)	65	67
High (above 4400)	69	71

Day temperatures were seasonally adjusted in compartments A and D for ventilation and cooling at 65°F March 15 to October 15, and 61°F the balance of the year. The varieties White Sim, Debutante and Coquette were used as test plants spaced at three per square foot. While some varietal differences in response were noted, these were of minor importance in the results shown in Table 1.

Yield or grade of carnations was not significantly affected by either seasonally adjusted day temperatures or those correlated with incident light minute by minute (Table 1). The yield and grade data for CO_2 treatments was arbitrarily grouped in two periods, with the data to January 1 indicating no differences between the treated plants and the controls. From January on there was a visible difference in grade of flowers so data from this time to the end of the experiment was grouped and analyzed by monthly periods. The increase in yield and number of fancy flowers produced by the CO_2 treated plants was highly significant (Table 1). Young plants in their first year produced 12 and 14 percent more fancy and total flowers from January to June when the CO_2 level was raised an average of 60-75 ppm from September through March.

The increase or decrease in mean monthly yield of fancy grade and total carnations is plotted in Figure 1, comparing CO_2 treated plants with the controls. A small increase in yield of fancy flowers is indicated from the first month of treatment. A net gain in total yield is not apparent until March or April, approximately six months after additions of CO_2 were started.

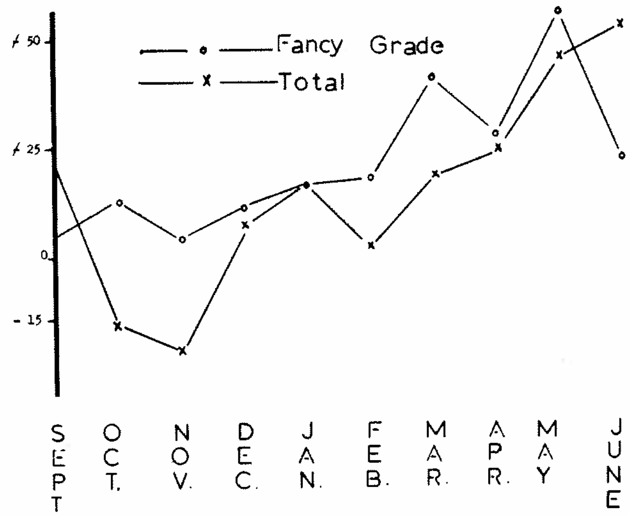

Figure 1.--Increase or decrease in mean monthly yield of CO_2 treated, first-year carnations. CO_2 added from September 11 to April 2.

Table 1. Effects of additional CO_2 and two systems of day temperature control on mean yield and grade of first-year carnations.

	Design	Short	Stand	Fancy	Total Yield[a]
CO_2 added	37	30	306	1057**	1430**
No CO_2 added	40	40	310	866	1256
Minimum difference for significance at 1% level				65	90
Manual temperature control	38	48	323	954	1363
Automatic control	38	22	293	969	1322

[a]Yield from January 1 to June 27, 1963.

Experiment 2

Three separate houses 15 by 18 feet containing one-year-old carnation plants were used in this experiment. One of the houses was covered with glass and the other two with new fiberglass. Beginning in November, temperatures in all houses were controlled at 54°F nights and 70°F days. On January 19, a propane burner was attached to the glass and one fiberglass house for CO_2 supply. No attempt was made to control the CO_2 concentrations in the two houses. The burner operated from 6:30 a.m. to 5 p.m. until April 17. From measurements on random days, CO_2 concentration varied from 400 ppm when ventilating fans were on to as high as 1700 ppm when the system was closed.

All flowers of the variety White Pikes Peak cut after January 19 were weighed to the nearest gram. An increase in weight of the CO_2 treated carnations corresponded with the improvement in grade visible within three weeks after the start of CO_2 additions. Weekly mean weights of flowers are plotted in Figure 2. The increase in weight of flowers in the untreated house is assumed the normal recovery in grade following a winter when carnations are grown at higher than optimum temperatures.

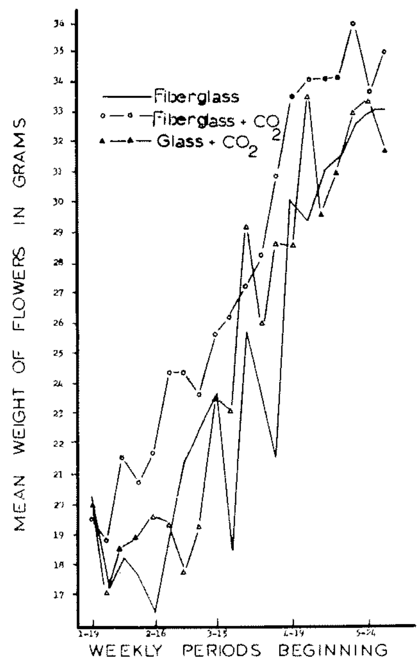

Figure 2.--The effect of CO_2 on weekly mean weights of carnation flowers. CO_2 additions started January 19.

Table 2 gives the yield and grade of White Pikes Peak carnations from the three houses from February 2 to June 20, 1964. Additions of CO_2 to the fiberglass house increased yield during this period by 33%, with fancy grade flowers up 70%. Supplementing CO_2 in the glass house increased yield 29% and fancy grade flowers 24%. A distinct increase in yield can be seen beginning the 12th to 13th weeks following start of CO_2 (Figure 3).

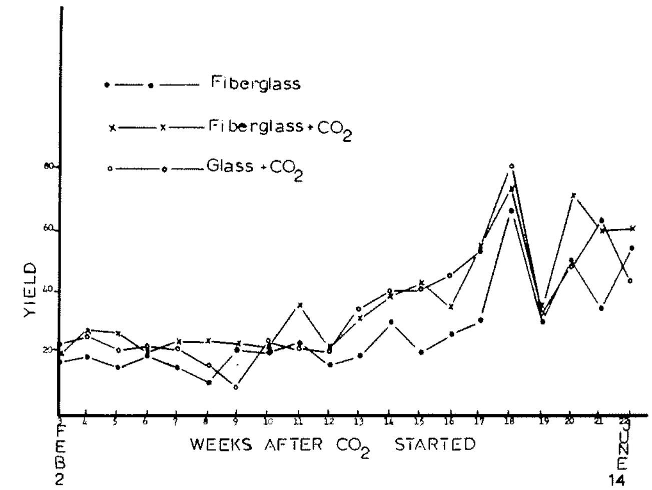

Figure 3.--Yield of 2-year-old carnations in three structures from the 3rd to 22nd weeks after additions of CO_2 were started.

Experiment 3

The plants used in Experiment 1 were grown under the same environmental conditions from June to September. One additional variety was planted on July 6 as rooted cuttings, and the yield data for the four varieties grouped in this experiment. On October 1, CO_2 and temperature treatments were started in an attempt to find relationships between CO_2 concentration and temperature.

Table 2. Yield and grade of White Pikes Peak carnation from three structures - February 2 to June 20, 1964.

	Grade					Yield	
	Des.	Short	Stand.	Fancy	Mean	Total	Per ft.^{2}
Fiberglass + CO_2	40	75	232	370	4.30	717	27.6
Glass + CO_2	47	102	272	270	4.11	691	26.6
Fiberglass	31	58	230	218	4.18	537	20.7

The temperatures in the four compartments were adjusted in late September to the following regimes:

	Night	Day
A	55°F	Automated with light 61°F to 73°F
B	55°F	Automated with light 57°F to 69°F
C	55°F	Automated with light 57°F to 69°F
D	53°F	Heat to 60°F, cool at 66°F

CO_2 was added to compartments A, B, and C and levels were constantly monitored throughout the fall and winter. The mean daily concentration in a compartment varied with the percent of ventilation time, as no CO_2 was added when ventilation fans were on. Mean daily CO_2 concentrations for the four compartments from November through February varied as follows: A - 575 to 930 ppm; B - 379 to 670 ppm; C - 300 to 550 ppm; and D - 250 to 310 ppm.

Yield data from January through May is shown in Table 3. The increase in temperature in compartment C more than nullified any effects caused by elevating average CO_2 levels by approximately 100 ppm. The raising of CO_2 concentration approximately 200 ppm (compartment B) significantly increased yield at this higher temperature. As day temperatures were raised another 4 degrees (compartment A) yield was significantly reduced below that of control D. In spite of a high CO_2 level averaging approximately 700 ppm, the plants at this higher temperature became hardened and lost flower size, typical reactions to higher than optimum day temperature. Significantly more design grade and fewer fancy grade flowers were produced in compartment A.

Discussion and Summary

Summer planted carnations in their first year have a limited number of growths for the first crop, hence the addition of CO_2 had no effect on yield of this crop. Increasing CO_2 from September to March increased yield of the second (spring) crop of flowers probably by increasing the number of lateral growths produced at the base of first-crop flower stems. On the other hand, elevated CO_2 levels generated yield increases on older plants in approximately 13 weeks. Since this is about half the time required from initial growth to maturity of a carnation shoot, it is postulated that additional CO_2 stimulated semi-dormant laterals into productive growth.

As the CO_2 concentration of the greenhouse atmosphere was increased, the temperature requirement for carnations increased slightly. The greatest yield and the highest grade flowers were obtained in Experiment 3 with mean CO_2 approximately 200 ppm above atmosphere, night temperature 55F and day temperature maximum with high light of 69F. When day temperature was increased another 4 degrees, plants were hardened and yield reduced in spite of an additional increment of approximately 200 ppm of CO_2.

Flower grade was increased in much shorter time on old and young plants. This was evidenced by an increase in yield of fancy grade flowers the second month after CO_2 was started in Experiment 1, and by flower weight increase within three weeks in Experiment 2. The increase in yield of fancy grade flowers and in total yield was highly significant for CO_2 treated plants in both experiments.

Table 3. Yield of carnations from four temperature - CO_2 combinations - January to May, 1964.

	A		B		C		D	
Month	Fancy	Total	Fancy	Total	Fancy	Total	Fancy	Total
Jan.	150	308	112	214	156	307	171	314
Feb.	103	191	179	300	167	252	205	359
Mar.	200	311	324	478	239	349	226	338
Apr.	171	267	191	294	197	285	168	241
May	256	437	431	644	340	476	410	586
Total	880	1514	1339	2113	1099	1669	1180	1838

Variance required for significance	Fancy	Total
0.05	106	147
0.01	149	206

Seasonally adjusted day temperatures gave results on carnation yield and grade equal to minute by minute temperature control correlated with incident light. Light-adjusted temperatures increased ventilation time, decreasing the time CO_2 could be added.

Literature Cited

1. Gaastra, P. 1959. Photosynthesis of crop plants as influenced by light, carbon dioxide, temperature, and stomatal diffusion resistance. H. Veenman en Zonen N. V., Wageningen, Nederlands. 68p.

2. Goldsberry, Kenneth L. 1963. The effects of carbon dioxide on carnation growth. Proc. Amer. Soc. Hort. Sci. 83:753-760.

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5. Korns, C. H. 1962. Carnation growth as influenced by temperature adjusted with light intensity and by CO_2. Thesis M. Sc., Colorado State Univ. 41p.

6. Manring, J. D. 1960. Effect of solar energy on the optimum day temperature for carnation growth. Thesis M. Sc., Colorado State Univ. 95p.

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RECENT RESEARCH

Abstracts of selected papers presented at the American Society for Horticultural Science annual meeting at the University of Colorado, Boulder, August 23 to 26, 1964.

Freeman, R. N., and R. W. Langhans, Cornell University, Ithaca, New York. The influence of varying night and day temperatures upon the growth and development of Dianthus caryophyllus. var. White Sim. In a two year study the response of White Sim carnations to varying day and night temperatures has been investigated. Using a 5 x 5 factorial arrangement of day and night temperatures, 25 temperature combinations were achieved. Day and night temperatures affect the mean grade, splitting, stem strength, stem diameter, leaf width, petal sizes, petal burn and the formation of malformed flowers.

Freeman, R. N., and R. W. Langhans, Cornell University, Ithaca, New York. The influence of daylength and temperature on the growth and development of Dianthus caryophyllus var. White Sim. Both daylength and temperature exhibits considerable effects upon the growth and development of White Sim carnation. Growing carnations at temperatures ranging from 40^{o} to $80^{o}F$ and using 3 daylengths at each temperature resulted in long day plants (18 hrs.) cropping first then followed by plants subjected to natural daylengths and finally by short day plants (9 hrs). Daylength, temperature and time of year were found to affect the morphological development of shoots and buds. Long day plants had less nodes and were taller in height than natural day plants or short day plants. This increase in height was due to an elongation of the internodes. Several other aspects as cropping time, fresh weight, petal number, development of extra axillary whorls of petalloids, petal size, splitting, malformation of flowers, stem strength and diameter, and mean grade were investigated.

Altstadt, Ralph, Colorado State University, Fort Collins, Colorado. Some factors affecting growth of carnation propagules. Carnation stock plants grown under cool temperatures (65 and $70^{o}F$) produced more cuttings of higher fresh weight per cutting than those grown at 75 and $80^{o}F$; moreover the cuttings from cool-grown stock plants produced more first-crop flowers and second-crop potential when planted in producing benches. In a separate experiment, cuttings from stock plants 4-6 months of age significantly outperformed those from stock plants 18 months of age. A study on grading of carnation cuttings showed that large cuttings of approximately 10 grams in weight and 8 pairs of expanded leaves outperformed those which weighed 4-6 grams and contained 5-6 pairs of expanded leaves. Fresh weight per cutting in the range of 4.5 to 12 grams and dry weight in the range of 1.0 to 1.5 grams was positively correlated with performance in the producing bench. Optimum preharvest environment for stock plants, harvesting cuttings at the proper time and the use of grading significantly increased yield and quality of first-crop flowers.

Goddard, George B., University of Massachusetts, Amherst, Massachusetts. Flower initiation and development in Lilium longiflorum. Lilium longiflorum plants cultivar were placed under 60 and 70 temperature after planting. The shoot tips were sampled weekly and studied microscopically. In view of the large complex apical dome of this species, other apices were dissected out and photographed. The vegetative and reproductive shoot apex was described as well as the frequency and location of cell divisions. Flower initiation occurs first on the flanks of the apex. Further initiation proceeds acropetally. Floral initiation occurred in 5 to 6 weeks regardless of temperature. Development of the flower bud appeared to be influenced more by temperature.

Goddard, George B., University of Massachusetts, Amherst, Massachusetts. Vegetative-reproductive reversibility of the shoot apex of Poinsettia by photoperiod. Poinsettia plants, cultivars Barbara Ecke Supreme and Paul Mikkelsen were placed in photo-inductive conditions and removed at one, two, and three week intervals. The shoot apices were sampled at regular intervals following the return to noninductive treatments. Under these conditions the primary cyathium failed to develop and three vegetative branches developed in place of the secondary cyathia. When plants were exposed to 2 weeks of inductive cycles followed by 2 weeks of noninductive cycles, the vegetative growth at the base of the primary cyathium became reproductive after producing only a few vegetative appendages. Some effects of temperature were also given.

Your editor,

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