Colorado Flower Growers Association Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY

Doris Fleischer, Executive Secretary

Bulletin 151 | 655 Broadway, Denver 3, Colorado | October 1962

Carbon Dioxide Research On Roses at Colorado State University

By K. L. Goldsberry and W. D. Holley

The third year of CO_2 research on roses has been completed at Colorado State University. More CO_2 has been used each year, and the point of maximum utilization has not been reached. The results obtained this past year have been particularly encouraging. Since only one house is available for this work, comparisons must be made between years. Varieties are kept constant, solar energy is measured, and since replanting is done after May 15, the comparison between years is confined to the first 18 weeks of the year.

From the base year of 1959 when no CO_2 was added, to 1962 when gas was added even when ventilation was open, the mean stem length for all varieties increased from 15.3 to 17.9 inches with head size increasing along with stem length. The yield increase for the first 18 weeks of the year has been approximately 25%, with a similar trend for the entire year.

Objectives for 1961-62

The major objective for this past year was to investigate the practicability of adding carbon dioxide to greenhouses when ventilation was open. Some of the questions we hoped to answer were: 1) How much gas must be added to maintain desired level when the ventilators are open? 2) What variation in CO_2 concentration at various points in a rose house can be expected with different methods of introducing the gas? 3) How much additional growth can be obtained by adding gas every day instead of just during days when the house is closed?

The additional effects of CO_2 on rose quality sought, but not completely answered, were a) dry matter percentage effects, b) effects on color, c) effects on keeping life, and d) opening characteristics.

Table 1 shows the yield and grade of 6 benches of roses comprising 708 sq. ft. of bench area for 4 comparable years. The amount of CO_2 added and the solar energy during the 18-week period are also included in the table. The 6 benches were planted to the following varieties: 1 to Golden Rapture, 1 to Pink Delight, 1 to Better Times, 1 to Gorgeous and 2 to Red Delight. The year 1961 was somewhat out of line because of the poor performance of one of the varieties. If only 5 of the

Table I. Yield and grade of roses[a] for the first 18 weeks of 4 years with amounts of CO_2 added and total solar energy for the period.

Year	Grade 9	12	15	18	21	24	Total yield	Mean stem length in inches	CO_2 added cu. ft.	Total solar energy g. cal/cm²
1959	955	1738	2244	1427	614	227	7017	15.3	none	50,884
1960	844	1552	2297	1807	882	520	7891	15.7	561	49,833
1961	388	937	1872	1922	1328	1163	7611	17.5	1899	50,302
1962	320	951	2156	2468	1788	1288	8896	17.9	7678	54,653

[a]Five varieties occupying 708 sq. ft. of bench area.

benches are considered for this particular year, it would be intermediate between the year 1960 and the year 1962. Production for the year 1962 when gas was added every day was up from 12.7 to 16.9% depending upon which year it was compared with. Mean stem length has increased from 15.3 inches in 1959 to 17.9 inches in 1962, with head size increasing even more.

Ventilation and the use of CO_2

During the 1961-62 season the amount of ventilation was recorded in inches of opening and time, and for purposes of analysis was converted to inch-hours. The study was carried on from January 22 through April. Table 2 shows the relationship between amount of ventilation, amount of solar energy, maximum outside temperature, carbon dioxide use, and the difference between CO_2 outside and inside the rose greenhouse. Ventilation classes were arbitrarily grouped into 0, any ventilation up to 30 inch-hours, and ventilation above 30.

The CO_2 level can be maintained at any of these levels of ventilation, but our experience indicates less efficient use of CO_2 on days when over 30 inch-hours of ventilation is required per day. We believe carbon dioxide should be cut off when the ventilation required is over 30 inch-hours. Such a day would be typically sunny with an outside maximum temperature of 55° or higher. In Colorado, we have from 7 to 10 days in March that are in this category. The majority of April days are also of this type and are included in the table to show that CO_2 should be cut off around April 1. Principal stimulation from the use of CO_2 in April would be on June and July crops.

CO_2 in the Earth's Atmosphere

In order to obtain basic information relative to the causes for fluctuations in the CO_2 content of outside air, daily measurements of CO_2 inside and outside greenhouses, solar energy, temperature, falling moisture, humidity and barometric pressure were coded on IBM cards and sorted for various relationships. The period included was September 1961 to May 1962.

Table 2. The effects of ventilation on CO_2 usage and the average CO_2 concentrations maintained (Jan. 22 to March 31, 1962).

Mean ventilation in inch-hours	No. of days	Mean solar energy per day	Mean max. outside temp.	CO_2 used in cu.ft.	Mean outside CO_2 ppm	Mean inside CO_2 ppm	Difference
None	13	240	23.5	32.0	302	416	114
0 to 30	51	410	43.4	48.9	311	383	72
Above 30	7	472	59.8	62.5	306	378	72
For month of April							
0 to 30	11	410	54.7	55.8	299	381	82
Above 30	19	601	67.2	60.3	307	347	40

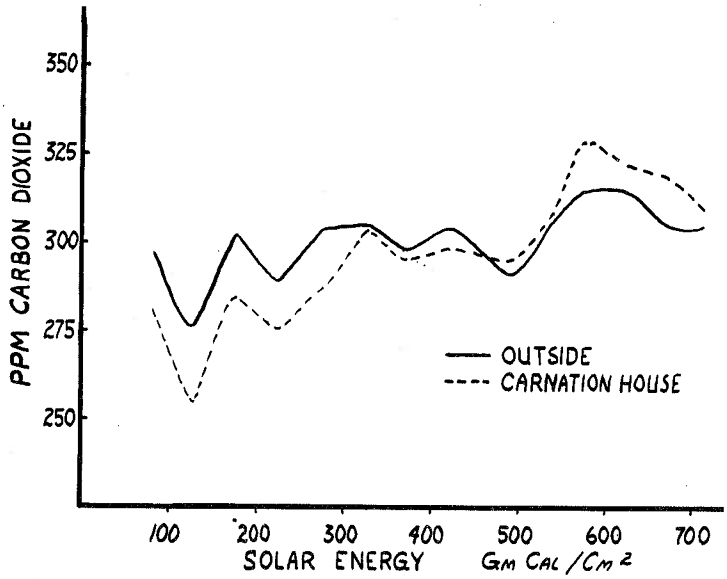

Fig. 1. Solar energy and carbon dioxide relationships measured at Fort Collins, Colorado, from September 1, 1961, to May 31, 1962.

The following general meteorological influences on the CO_2 concentration of the earth's atmosphere from September to May have been found by the authors at Fort Collins, Colorado. As solar energy increased from 100 to 700 g cal/cm^2 the CO_2 concentration increased approximately 25 ppm (Fig. 1). The CO_2 level fluctuated rather widely with temperature, but tended to decrease as temperature increased (Fig. 2). Increases in barometric pressure in the order of .8 inch resulted in average increases in CO_2 concentration from 280 to 305 ppm. As humidity increased from 30 to 90% the CO_2 level decreased from 305 to 292 ppm.

Carbon Dioxide in Greenhouse Atmosphere

The CO_2 level in the greenhouse is mainly related to the amount of solar energy available and the outside temperature. The CO_2 concentration in a carnation house increases as solar energy and outside temperature increase (Figs. 1 and 2). This trend is established by the ventilating system allowing the entry of fresh air for proportionally longer periods of time as both factors increase. Warm days and high light make ventilation necessary; thus, the CO_2 level approaches the outside concentration (Fig. 3). Colder and darker days cause a low CO_2 concentration, but the degree is still based on the amount of solar energy (Figs. 1 and 4).

Graphs for carnation greenhouses are used since complete seasonal records for a rose house in which no CO_2 was added are not available. Measurements of the CO_2 concentration in a closed rose house have been published previously and indicate the CO_2 level drops as much as 50 to 100 ppm below that in a carnation house on a given day.

A top ventilated greenhouse containing roses with an increased CO_2 atmosphere from 9:00 a.m. until 3:30 p.m. was greatly affected by variations in solar energy (Fig. 5). Increases in solar energy at 9:00, 11:45, 1:30, and 3:00 reduced the CO_2 concentration. Some ventilation was required because of the outside temperature (59° F.), rather than because of the solar energy level.

Carbon Dioxide Vs. Moisture

Air samples taken before and after passing through a wet evaporative pad used in greenhouse cooling contained approximately 290 ppm CO_2. When 10 cu ft/hr of CO_2 was injected into the air before it passed through the pads, the concentration was increased to 450 ppm. Upon passing through the wet pad the CO_2 concentration did not change, but did decrease to 350 ppm at 15' distance from the pad, probably because of mixing with other air.

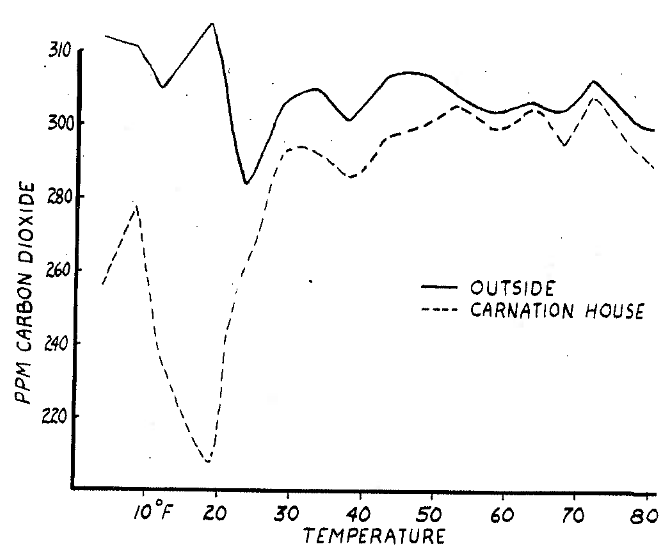

Fig. 2. Temperature and carbon dioxide relationships measured at Fort Collins, Colorado, from September 1, 1961 to May 31, 1962.

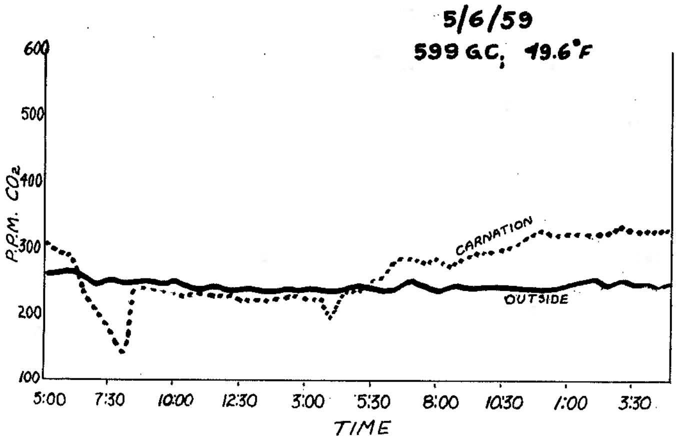

Fig. 3. The effect of ventilation on the CO_2 content of air in a carnation greenhouse. Fan ventilation operated continuously between 8 a.m. and 3:30 p.m.

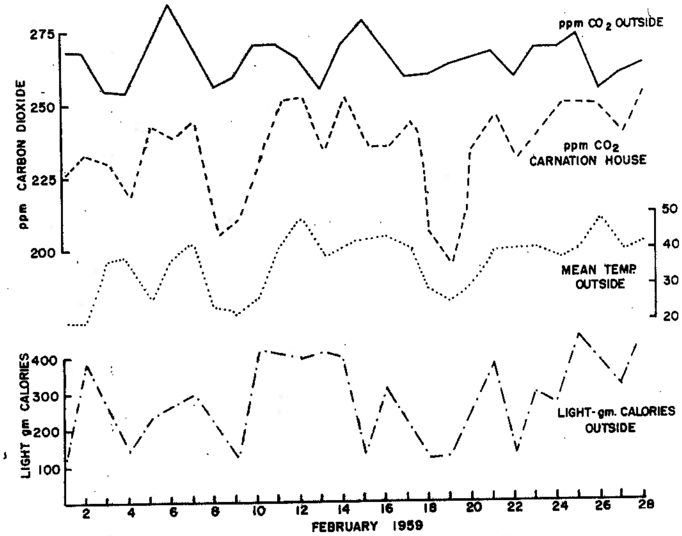

Fig. 4. Relationships between outside and inside CO_2 concentrations, outside temperature and light during February of 1959.

A polyethylene plastic tube having an 18" diameter was hung in a vertical position under a high pressure mist nozzle. Carbon dioxide was injected into the tube at a concentration of 550 ppm. When the mist was turned on, the CO_2 concentration was not altered. The concentration decreased instantly to approximately 325 ppm when the CO_2 source was removed. The CO_2 content of the air was measured at several locations from July 17-22, when no CO_2 was being added. Fig. 6 shows the mean CO_2 level of outside air, air on the cool side of a wet pad, and air in a top ventilated rose house where high pressure mist was used continuously. Although the level was consistently lower in the rose house, most of this difference could be expected without mist on a still day. Apparently free moisture in the greenhouse has little effect on the CO_2 concentration.

Diffusion of Carbon Dioxide

Carbon dioxide was injected at the rate of 10 cu ft/hr into a standard glasshouse containing a CO_2 concentration of approximately 240 ppm before injection. The injection area (A) concentration immediately began to increase and within 15 minutes reached a level of 470 ppm (Fig. 7). Areas B and C gradually increased in concentration and approached 270 ppm in the same period of time. Carbon dioxide flow was decreased to 5 cu ft/hr and area A started to decrease, while levels in areas B and C continued to increase. Within 50 minutes from the time of the original injection the CO_2 concentration throughout the house was 365 ppm.

The degree of CO_2 dispersion within a slightly vented greenhouse is relatively even (Fig. 5). Air movement through the ventilators apparently caused the CO_2 variations in the different sampling areas.

One CO_2 outlet per 1000 to 1500 sq. ft. should give adequate distribution unless ventilation is excessive.

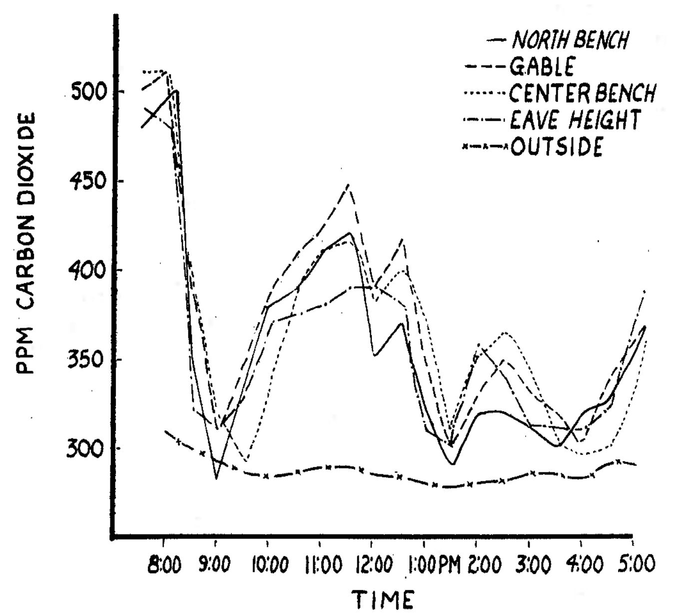

Fig. 5. Carbon dioxide levels measured at 5 points in a rose greenhouse which had one inch of ventilation at 9:00 a.m., increased to 2" at 1:45 p.m., closed at 4:00 p.m. Carbon dioxide was injected from one central outlet at the rate of 1 cu. ft./ 300 sq. ft/hr.

Criticisms of 1961-62 Work

The measurement of ventilation lacked accuracy. Since an attendant was not always present, ventilation had to be set by judgment, which is wrong about as much of the time as it is right. The house was sometimes too warm, but most of the time, it was colder than it should be. This means that more ventilation was used than necessary and therefore, CO_2 was wasted.

The rose house will be ventilated automatically with fans and polyethylene tubes during the 1962-63 season. From work already done with carnations, carbon dioxide can be added to roses a maximum percentage of the time in winter with automatic ventilation control, and temperature at 75° or 80° on sunny days can be maintained. This should allow the maximum use of CO_2 by the plants and maximum growth. Table 3 shows estimated usage of CO_2 in a rose range in Colorado on a typical year from September to March. This would require approximately 1500 cu. ft. of CO_2 per 300 sq. ft. of floor space, or /200 sq. ft. of bench area in most greenhouses. Any means that could be developed for increasing the time the plants are growing in a closed system should result in increased growth of the rose plants.

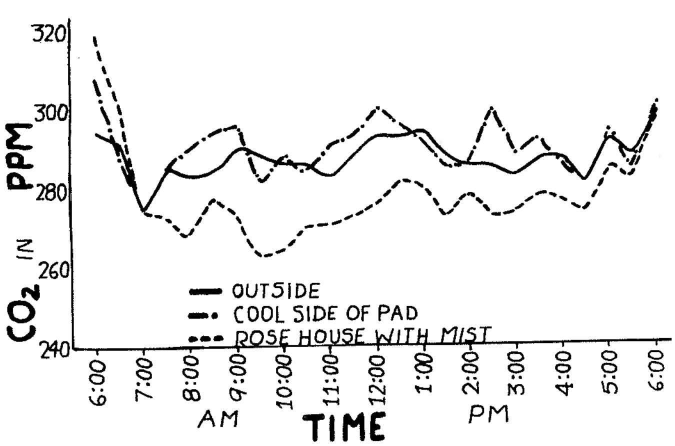

Fig. 6. Mean CO_2 concentrations in three locations measured from July 17-22, 1962.

The CO_2 level maintained in the rose house in 1961-62 was too variable. The difference in inside and outside CO_2 levels varied in February from as much as 205 to as little as 19 ppm. Ventilation played a big part in this, but solar energy was just as important an influence. The higher the solar energy, the more carbon dioxide required by the plants. When solar energy is high and the house remains closed because of cold outside temperature, the carbon dioxide level in the greenhouse reaches a minimum unless CO_2 is added. The addition of CO_2 is now being automatically controlled by solar energy on 3 levels. As light increases, the amount of CO_2 added is also increased.

Any time the ventilation is opened, the CO_2 flow is automatically doubled. With this method, we hope to control the CO_2 level within the greenhouse around 450 ppm ± 25 ppm.

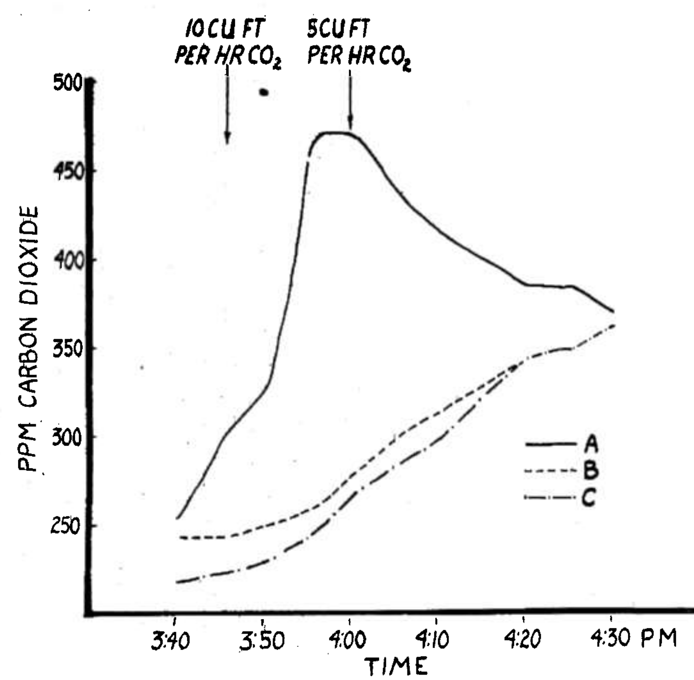

Fig. 7. The diffusion rate of CO_2 injected from one outlet 6' above ground, 15' from the end and midway from the sides of a 35' x 80' greenhouse. A: 15' from the point of injection 5' above ground. C: 50' from the injection point, and 5' above ground. B: 13' directly above C.

Table 3. Estimated volume of carbon dioxide use by months on roses in Colorado with fully automatic equipment.

	cu ft/ 300 sq. ft. of greenhouse	% of yearly total
September	160	11
October	210	14
November	270	18
December	250	17
January	240	17
February	200	13
March	170	11
TOTAL	1500	100

Acknowledgement

This investigation is being supported jointly by the Joseph H. Hill Memorial Foundation, Colorado Flower Growers Association Inc., Liquid Carbonics Division of General Dynamics Corporation and the Colorado Agricultural Experiment Station.

Your editor,

W D Holley

COLORADO FLOWER GROWERS ASSOCIATION, INC.
OFFICE OF EDITOR
W. D. HOLLEY
Colorado State University
Fort Collins, Colorado

FIRST CLASS