Colorado Flower Growers Association Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY

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Effects of Carbon Dioxide on Carnation Growth

By

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Red Gayety carnations were grown for one year in vinyl enclosed chambers in which carbon dioxide concentrations of 200, 350, and 550 ppm were maintained in the atmosphere. The following pertinent measurements were obtained:

1. Yield increased 38 per cent in the 550, and 30 per cent in 350 ppm when compared to the 200 ppm concentration.

2. The percentage of dry matter increased approximately 0.7 per cent for 350, and 1.0 per cent for the 550 level over that from the 200 ppm concentration.

3. Stem length was shortened slightly as carbon dioxide increased.

4. The first and second crops in the 350 and 550 levels flowered two weeks ahead of the 200 level.

5. There were similar amounts of sucrose and fructose in young vegetative shoots produced at all levels.

6. Cut flower life in a 70°F keeping room was approximately 10 days for flowers produced in the three CO_2 levels.

/1. This is a part of the thesis by the author in partial fulfillment of the requirements for the Master's Degree at Colorado State University.

Background

In the past five years, much progress has been made in the control of greenhouse environment. With the advent of automation for heating and air conditioning temperatures can now be controlled within a few degrees. Nutritional needs can be more easily supplied with fertilizer injection systems. Optimum moisture levels are also within the grower's control. While light is dependent upon weather and climate, strides are being made in the modification of growing structures. The near optimum relationships of the above factors in the environment complex have no doubt led to increased production and quality. It is quite possible that further increases in plant growth may be obtained by atmospheric fertilization with carbon dioxide.

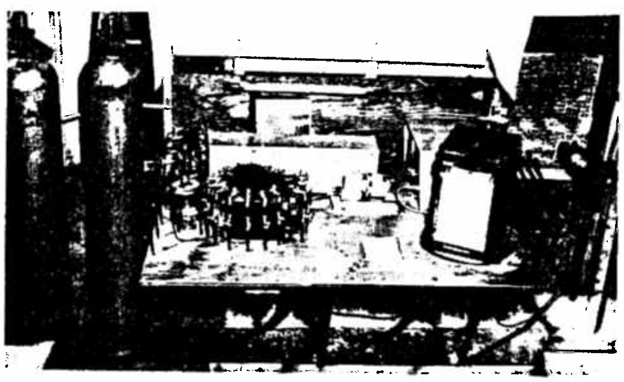
Early investigators have indicated that CO_2 assimilation is greatest at high light intensities. Optimum temperature has been found to vary with light intensity, and optimum light intensity has been found to vary with the water supply available to plants. Blackman, according to Meyer and Anderson (1) has postulated his "principle of limiting factors", which infers that the speed of the plant growth process is dependent on a number of separate factors, the rate of which is limited by the factor in least supply.

Several i. ˌestigators have increased the CO_2 concentration of the atmosphere surrounding plants with positive results of increased plant growth. Other investigators have reported no increase in dry matter production from CO_2 fertilization. To investigate potential uses for carbon dioxide in modern greenhouse practices, facilities were installed and experiments started in the summer of 1958.

Materials and Equipment

A Beckman model LB 15A infrared gas analyzer was installed to insure accurate measurements of the carbon dioxide in the atmosphere surrounding growing plants. The instrument, which consists of an analyzer and an amplifier, contained a cell capable of analyzing carbon dioxide concentrations ranging from 0 to 600 ppm. Operation is based on the absorption of infrared radiations of approximately 4.23 mu wavelength. Absorption varies in proportion to the amount of CO_2 in the air being sampled, with accuracy within one per cent of full scale. The analyzer was connected to an Esterline-Angus recorder for continuous records of CO_2 concentrations.

Maximum utilization of the infrared analyzer was achieved by installing a multiple port selector valve (Fig. 1). The valve assembly consisted of a 1/20 HP Bodine motor geared to 1 rpm and connected to a Boston reducing gear unit, which gave a drive speed of 2 rphr. The 16 ports on the revolving cone allowed air samples to be taken from each port for approximately 100 seconds every half hour. Each port was connected to a 1/4" OD copper tube which conveyed the air samples from the sampling area.



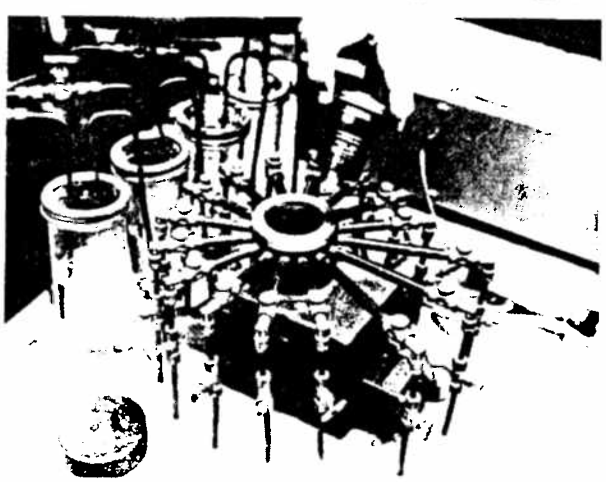


Fig. 1. Infrared gas analyser and recorder with enlarged photo of multiple port valve and metering system.

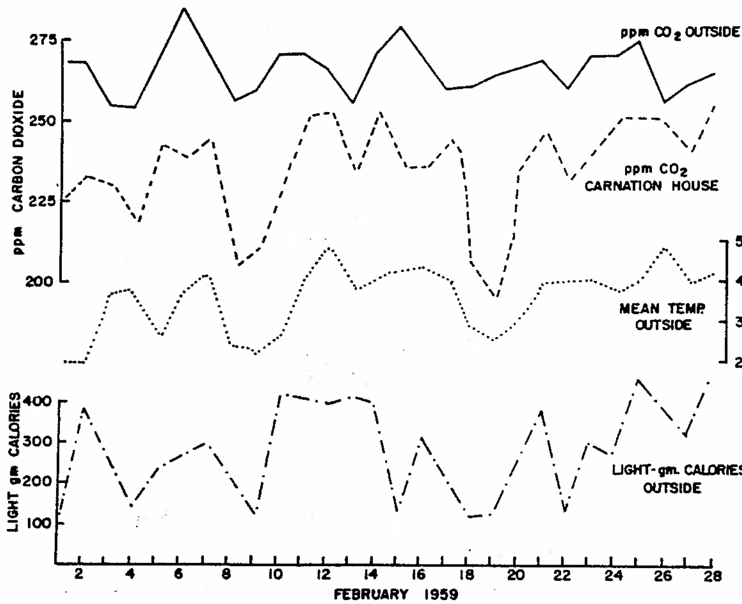


Fig. 2. Relationship of temperature and light to inside and outside atmospheric levels of carbon dioxide.

A model 2 dyna pump was used to pull air through the sampling tubes and selector valve, forcing the sample through a cotton filter into the analyzer. The rate of flow through the sampling tubes was 0.9 to 1.10 liters per minute, depending on the length of the tube.

Atmospheric measurements

Continuous records of carbon dioxide in the outside atmosphere at Fort Collins have been kept for over two years. The average concentration during daylight hours has varied from 207 to as high as 362 ppm. The month of February 1959 has been selected to show the relationship between solar energy, mean temperature, carbon dioxide outside and inside a greenhouse (Fig. 2). On cold days, when light is insufficient to cause ventilation, CO_2 levels inside a greenhouse may become extremely limiting to growth. On warmer days, with full ventilation, greenhouse levels approach those in the outside atmosphere. Carbon dioxide levels as low as

200 ppm, or below, are not uncommon when greenhouses remain closed during the daylight hours.

Facilities for Carnation Investigation

Four chambers, each containing 520 cu. ft. of space, were constructed on a 35' by 15' area inside a greenhouse section. The set of chambers was aligned east to west, built of light wood framework with plywood floors, and covered with clear polyvinyl film. Each chamber contained a duct system for recirculating and cooling the air. The recirculating system consisted of a return air manifold on the rear of the chamber, which collected the air and conducted it through an 18" round duct, across the evaporative coil and into a plenum. The plenum, containing louvers, distributed the air into the main chamber (Fig. 3). Air was circulated by a unit consisting of a 1/4 HP motor and 20" fan capable of moving free air at the rate of 4400 CFM. In this installation the air change was approximately 2200 CFM, producing an air flow through the plants of 130 FPM. A two-HP compressor with two-ton evaporative coil was used to remove excess solar heat from each chamber. Temperature could be maintained as low as 53°F on the brightest days with this equipment.

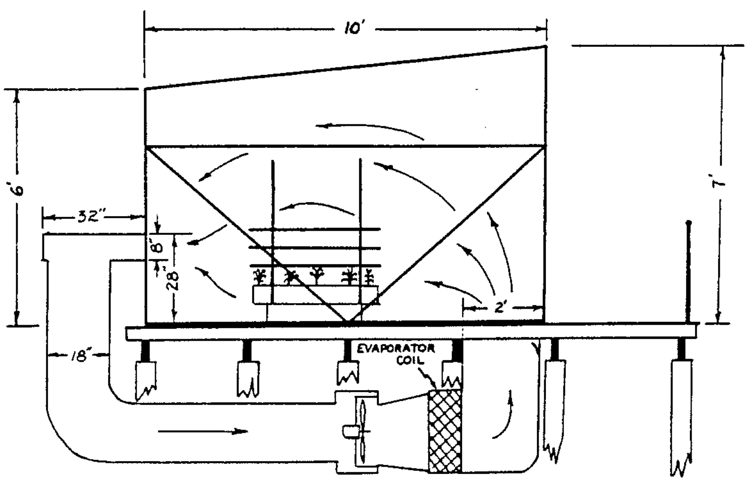


Fig. 3. Diagram of one of the environmental chambers.

Carbon dioxide for this investigation was obtained from a dry ice converter and metered through a specially designed manifold of glass jars (Fig. 1) into the chambers. By means of a pressure regulator and manual adjustment of the bubbling rate through water, it was possible to control the levels of CO_2 within the chambers. Once the rate of flow was adjusted, the pressure regulator could be used to evenly increase or decrease flow during variable light periods.

Experiment

Five rooted cuttings of Red Gayety carnation were planted in each of six boxes of volcanic scoria per chamber on May 28, 1960. The plants were watered at first signs of wilting with a complete nutrient solution containing the following: nitrogen 187 ppm; potassium 210 ppm; phosphorus 150 ppm; magnesium 18 ppm; iron 3 ppm; and boron 1½ ppm. Additional magnesium and the other essential elements were available in the tap water. This nutrient solution is 50 per cent stronger than that generally used at Colorado State University and was established for higher carbon dioxide levels by preliminary investigation.

The following carbon dioxide concentrations were manually controlled as closely as was possible: chamber 1, 200 ppm; chamber 2, 350 ppm; chamber 3, 550 ppm; and chamber 4, 350 ppm, a check on chamber 2. The carbon dioxide levels were brought to that of the surrounding greenhouse at night by opening the doors. This level varied from 350 to 450 ppm depending upon the amount and size of vegetation present.

All plants were pinched once when well established. One plant was pulled from each box on July 30, and another on September 10. These plants were weighed and dried (Table 1) while the remaining three plants in each box were grown on for yield and quality data. An increase in production of dry matter and in percentage of dry matter was indicated when carbon dioxide concentration was increased from 200 to 550 ppm. The 15-week plants showed 18 and 42 per cent increases in dry matter for 350 and 550 ppm, respectively. Increases in percentage of dry matter were approximately 2 per cent for each of the higher levels.

Table 1. Effects of three carbon dioxide levels on fresh and dry weights of young Red Gayety carnation plants.

	Carbon dioxide concentrations			
Harvested	200 ppm	350 ppm	350 ppm	550 ppm
9 weeks after planting				
Mean fresh wt. in grams	65.5	69.6	79.0	80.3
Mean dry wt. in grams	9.7	11.0	13.9	13.5
Percentage of dry matter	14.7	15.8	17.5	16.8
15 weeks after planting				
Mean fresh weight	208.0	222.5	218.0	242.0
Mean dry weight	38.9	46.7	45.1	55.3
Percentage dry matter	18.7	20.9	20.7	22.8

Yield

Eighteen plants were grown in each chamber until the experiment was terminated on June 2, 1961. A summation of the influence of carbon dioxide concentration on yield is shown in Table 2. The accumulative yield by monthly periods indicates a definite relationship to increases in carbon dioxide. The 200 ppm level continuously produced less flowers than any other chamber. The yield from the 350 and 550 ppm levels remained similar until the end of February. From this point on, the 550 level showed an increase over 350 ppm. A slight increase in malformed flowers was indicated for the higher CO_2 levels.

Table 2. Effects of increased carbon dioxide on yield of Red Gayety carnations.

	Carbon dioxide concentrations			
	200 ppm	350 ppm	350 ppm	550 ppm
Accumulative yield for months ending:				
September 30, 1960	16	35	44	43
October 31, 1960	73	83	82	83
November 30, 1960	91	94	91	93
December 31, 1960	105	129	139	151
January 31, 1961	153	201	224	236
February 28, 1961	218	272	296	302
March 31, 1961	274	330	346	368
April 30, 1961	324	401	390	436
May 31, 1961	378	490	477	517
Total yield through June 2	381	494	482	521
Per cent malformed flowers	3.94	5.46	7.05	5.57
Speed of crop return				
Midpoint of first crop (1960)	Oct. 17	Oct. 6	Oct. 3	Oct. 3
Midpoint of second crop (1961)	Mar. 2	Feb. 21	Feb. 11	Feb. 16

By tagging the laterals remaining as the first crop was cut, midpoints of the first and second crops could be established. While there was virtually no difference between the midpoints of crops grown in 350 and 550 ppm, the 200 ppm level was approximately two weeks behind in both first and second crops.

Effects of the three levels of carbon dioxide on several physical measurements of the cut flowers are summarized in Table 3. While differences in stem length were small, the relationship was inverse. As the carbon dioxide concentration was increased stem length was shortened. The fresh and dry weights of the flowers were approximately the same in all levels. There was a consistent and perhaps quite important difference in percentage of dry matter of the cut flowers (Fig. 4). The curves in this figure show typical reduced dry matter percentages in midwinter as light decreases. The dry matter percentage for the 8-month period averaged one per cent greater for 550, and 0.7 per cent greater for 350 when compared to the 200 ppm level.

Table 3. Summary of the effects of increased carbon dioxide concentrations on some physical measurements of carnation cut flowers.

	Carbon dioxide concentrations			
	200 ppm	350 ppm	350 ppm	550 ppm
Mean length of flowers in inches. Sept. 7, 1960 to April 24, 1961.	27.8	26.0	26.1	25.6
Mean fresh weight of flowers in grams. Sept. 7, 1960 to April 24, 1961.	31.2	30.8	30.4	31.0
Per cent dry matter of flowers. Sept. 7, 1960 to April 24, 1961.	19.7	20.5	20.3	20.7
Keeping quality in days. May 5 to June 2				
Cut every second day	10.2	10.2	10.5	10.0
Cut every third day	10.1	10.0	10.6	10.3

Cut flower life was measured in a controlled 70°F room for flowers cut from May 5 to June 2. There were no significant differences caused by the carbon dioxide levels, nor were there differences in life of flowers cut from these closed chambers on two-day or three-day intervals.

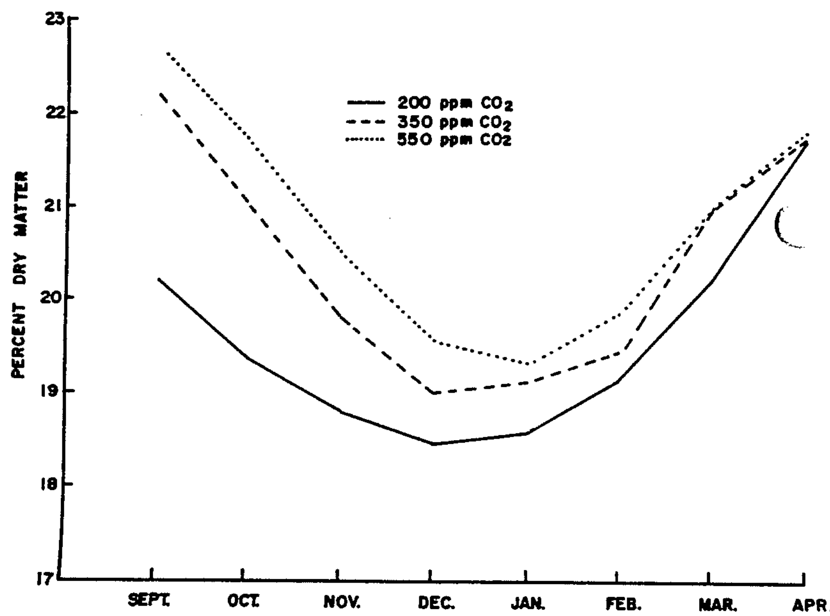


Fig. 4. Percentage of dry matter in carnations produced in three levels of carbon dioxide.

The amounts of sucrose and fructose in vegetative growths taken from each carbon dioxide concentration were measured chromatographically on one instance during the spring. The amounts of these sugars in this tissue were similar.

Discussion of results

Increased yield, shorter time between crops and higher dry matter percentage are the outstanding results of this investigation. The first two lead to more flowers per unit of area. The third promises better shipping quality in winter.

The results of this experiment indicate that low carbon dioxide levels may slow down the development of a flower, while higher levels can speed this up. Possibly a basic amount of dry matter is required before a flower can complete its development. If carbon dioxide levels are increased and other factors are not limiting, the basic amount of dry matter is accumulated in a shorter time. Extra dry matter over and above that needed for the developing flowers can then go to the lateral breaks, causing them to develop earlier, thereby shortening the time interval between crops.

Other than higher percentage of dry matter, there were no indications that higher quality resulted from increased CO_2 on carnations. Flower color was outstanding throughout the experiment. Cut flower life was excellent and did not decrease with with 3-day interval cutting. Sugar content of the lateral growths was similar and in good supply. These quality factors are attributed to the closed system of environment which had no appreciable fluctuations of factors other than light.

Literature cited

1. Meyer, B. and D. Anderson. 1939. Plant Physiology. D. Van Nostrand Co., Inc., New York. 696 p.